

STRATIGRAPHY AND BIOSTRATIGRAPHY
OF LATE CENOZOIC DEPOSITS
IN CENTRAL SIOUX COUNTY,
WESTERN NEBRASKA

MORRIS F. SKINNER, SHIRLEY M. SKINNER, AND
RAYMOND J. GOORIS

BULLETIN
OF THE
AMERICAN MUSEUM OF NATURAL HISTORY
VOLUME 158 : ARTICLE 5 NEW YORK : 1977

STRATIGRAPHY AND BIOSTRATIGRAPHY
OF LATE CENOZOIC DEPOSITS
IN CENTRAL SIOUX COUNTY,
WESTERN NEBRASKA

MORRIS F. SKINNER

Frick Curator Emeritus

Department of Vertebrate Paleontology

The American Museum of Natural History

SHIRLEY M. SKINNER

Scientific Assistant

Department of Vertebrate Paleontology

The American Museum of Natural History

RAYMOND J. GOORIS

Scientific Assistant

Department of Vertebrate Paleontology

The American Museum of Natural History

BULLETIN

OF THE

AMERICAN MUSEUM OF NATURAL HISTORY

VOLUME 158 : ARTICLE 5

NEW YORK : 1977

BULLETIN OF THE AMERICAN MUSEUM OF NATURAL HISTORY

Volume 158, article 5, pages 263-370, figures 1-17, tables 1-4

Issued May 26, 1977

Price. \$7.60 a copy

ISSN 0003-0090

This article completes Vol. 158.

Copyright © The American Museum of Natural History 1977

CONTENTS

Abstract	271
Introduction	271
Acknowledgments	273
Abbreviations	274
Location and Extent of the Area	274
Method of Elevation Control	275
Maps Used for Drainages and Quarry Sites	275
Historical Review	277
The 1908 American Museum of Natural History Expedition	277
Cook's Work From 1908 to 1962	279
The 1914 Princeton University Expedition	279
Whitford's Work for the American Museum of Natural History in 1916	280
The 1918-1927 American Museum of Natural History Expeditions	281
The 1932-1973 Frick Laboratory Expeditions	283
Discussion	284
Tertiary System. Stratigraphy of the Sedimentary Rocks	290
Arikaree Group	290
Harrison Formation	290
Hemingford Group	292
Marsland Formation	292
Sheep Creek Formation	295
The Lower Part of the Sheep Creek Formation	297
The Middle Part of the Sheep Creek Formation	298
The Upper Part of the Sheep Creek Formation	299
Olcott Formation, New Name	300
Ogallala Group	306
The Snake Creek Formation	306
Murphy Member of Snake Creek Formation, New Name	308
Laucomer Member of Snake Creek Formation, New Name	310
Type Member of Snake Creek Formation	310
Johnson Member of Snake Creek Formation, New Name	311
Regional and Local Paleogeomorphology	314
Aggradation and Degradation in Northwestern Nebraska	315
Cycle 1	315
Post-Arikareean to Early Hemingfordian	315
Cycle 2	316
Medial to Late Medial Hemingfordian	316
Cycle 3	317
Late Hemingfordian	317
Cycle 4	318
Late Hemingfordian and Early Barstovian	318
Cycle 5	320
Late Barstovian, Valentinian, Clarendonian, and Hemphillian	320
Cycle 6	321
Late Hemphillian, Blancan, and Recent	321

Quarries of the Sheep Creek, Olcott, and Snake Creek Formations	322
Introduction	322
Quarries in the Sheep Creek Formation	325
Early Miocene (Late Hemingfordian)	325
Lower Part of Sheep Creek Formation	325
Middle Part of Sheep Creek Formation	325
Quarries in the Olcott Formation	329
Medial Miocene (Early Barstovian)	329
Quarries of Subcycle 1	329
Quarries of Subcycle 2	331
Quarries of Subcycle 3	333
Quarries in the Olcott Formation, Relation to Subcycles Unknown	335
Quarries in the Snake Creek Formation	337
Laucomer Member (New) of the Snake Creek Formation	337
Medial Miocene (Late Clarendonian)	337
The Lower Part of the Johnson Member (New) of the Snake Creek Formation	339
Late Miocene (Early Hemphillian)	339
The Upper Part of the Johnson Member (New) of the Snake Creek Formation	340
Late Miocene (Late Hemphillian)	340
Systematics	340
The Sheep Creek Fauna (Late Hemingfordian), Sheep Creek Formation	342
Class Reptilia	342
Order Chelonia	342
Family Testudinidae	342
Class Aves	342
Order Accipitriformes	342
Family Buteonidae	342
Family Accipitridae	342
Order Galliformes	342
Family Phasianidae	342
Order Ralliformes	342
Family Aramidae	342
Order Psittaciformes	342
Family Psittacidae	342
Class Mammalia	342
Order Insectivora	342
Family Erinaceidae	342
Order Rodentia	342
Family Mylagaulidae	342
Order Carnivora	342
Family Canidae	342
Family Amphicyonidae	342
Family Mustelidae	342
Order Perissodactyla	343
Family Equidae	343
Family Chalicotheriidae	344
Order Artiodactyla	344
Family Tayassuidae	344
Family Merycoidodontidae	344
Suborder Tylopoda	344
Family Camelidae	344

Suborder Ruminantia	344
Family Cervidae	344
Family Antilocapridae	345
The Lower Snake Creek Fauna (Early Barstovian), Olcott Formation	345
Class Amphibia	345
Order Urodela	345
Family Cryptobranchidea	345
Class Reptilia	345
Order Crocodilia	345
Family Crocodylidae	345
Order Chelonia	345
Family Trionychidae	345
Family Testudinidae	345
Class Aves.	345
Order Anseriformes	345
Family Anatidae	345
Order Accipitriformes	345
Family Buteonidae	345
Class Mammalia	346
Order Insectivora	346
Family Erinaceidae	346
Order Rodentia	346
Family Heteromyidae	346
Family Mylagaulidae	346
Family Castoridae	346
Family Cricetidae	346
Order Carnivora	346
Family Canidae	346
Family Amphicyonidae	346
Family Procyonidae	346
Family Mustelidae	346
Family Felidae	347
Order Perissodactyla	347
Family Equidae	347
Family Chalicotheriidae	347
Family Rhinocerotidae	348
Order Artiodactyla	348
Family Tayassuidae	348
Family Merycoidodontidae	348
Suborder Tylopoda	348
Family Protoceratidae	348
Family Camelidae	348
Suborder Ruminantia	349
Family Cervidae	349
Family Antilocapridae	349
The Faunas of the Snake Creek Formation	349
The Local Fauna (Early Clarendonian), Murphy Member	349
Class Reptilia	349
Order Chelonia	349
Family Testudinidae	349
Class Mammalia	349

Order Lagomorpha	349
Family Leporidae	349
Order Artiodactyla	350
Suborder Suiformes	350
Family Tayassuidae	350
Family Merycoidodontidae	350
Suborder Tylopoda	350
Family Camelidae	350
Suborder Ruminantia	351
Family Cervidae	351
<i>Longirostromeryx wellsi</i> (Matthew, 1904) Frick, 1937	351
The Snake Creek Fauna (Late Clarendonian), Laucomer Member	351
The Type Fauna of the Snake Creek Formation	351
Class Aves	351
Order Galliformes	351
Family Cracidae	351
Order Ralliformes	351
Family Gruidae	351
Class Mammalia	352
Order Rodentia	352
Family Castoridae	352
Order Edentata	352
Family Megalonychidae	352
Order Carnivora	352
Family Canidae	352
Family Mustelidae	353
Order Proboscidea	353
Family Gomphotheriidae	353
Order Perissodactyla	353
Family Equidae	353
Order Artiodactyla	355
Suborder Suiformes	355
Family Tayassuidae	355
Infraorder Oreodonta	355
Family Merycoidodontidae	355
The <i>Aphelops</i> Draw Fauna (Early Hemphillian), Johnson Member	355
Class Aves	355
Order Accipitriformes	355
Family Buteonidae	355
Class Mammalia	355
Order Rodentia	355
Family Sciuridae	355
Family Castoridae	356
Order Edentata	356
Family Megalonychidae	356
Order Carnivora	356
Family Canidae	356
Family Mustelidae	356
Family Felidae	356
Order Proboscidea	356
Family Mammutidae	356

Family Gomphotheriidae	356
Order Perissodactyla	357
Family Rhinocerotidae	357
Family Equidae	357
Order Artiodactyla	357
Family Merycoidodontidae	357
Suborder Tylopoda	357
Family Camelidae	357
Family Antilocapridae	357
Family Bovidae	357
The ZX Bar Local Fauna (Late Hemphillian), Johnson Member	358
Class Mammalia	358
Order Insectivora	358
Family Talpidae	358
Family Heteromyidae	358
Order Edentata	358
Family Megalonychidae	358
Order Carnivora	358
Family Canidae	358
Family Mustelidae	358
Family Ursidae	358
Order Perissodactyla	358
Family Equidae	358
Order Artiodactyla	359
Family Tayassuidae	359
?Family Merycoidodontidae	359
Suborder Tylopoda	360
Family Camelidae	360
Suborder Ruminantia	360
Family Cervidae	360
Family Bovidae	360
Summary	361
Literature Cited	363
Index of Quarries and Synonyms	369
Index for Figures	371

ABSTRACT

The objectives of the present report are (1) to interpret in detail the geology of the Sheep Creek-Snake Creek beds of Sioux County, northwestern Nebraska, which have produced more than 30,000 vertebrate fossil specimens, and (2) to supply precise data for these fossils so that future research will conform to historical data and field observations.

An erosional remnant of former high plains, which contains the historic Sheep Creek-Snake Creek beds, has preserved a record of geologic history from Early through Late Miocene time. A remnant of a paleovalley that once contained the streams of the Early Miocene Sheep Creek (Late Hemingfordian) and the Late Miocene Snake Creek formations can be seen in the northwest part of the area. The early Medial Miocene (Early

Barstovian) Olcott Formation (New), the former Lower Snake Creek beds of Matthew, 1924a, crops out in the classic Sinclair Draw and Olcott Hill area that was explored in the early 1900s. The revised and restricted Snake Creek Formation is divided into three new members: the Medial Miocene Murphy Member (Early Clarendonian) on Olcott Hill and in East *Pliohippus* Draw, the Medial Miocene Laucomer Member (Late Clarendonian) on Olcott Hill, and the Late Miocene Johnson Member that carries Early and Late Hemphillian faunas.

The present report also deals with the documentary data of early collectors whose numerous synonymous names for some of the 57 quarries has led to the dissipation of faunas.

INTRODUCTION

The fossiliferous Sheep Creek-Snake Creek beds of authors are remnants of Medial to Late Tertiary paleovalley deposits that formed part of a once continuous plain and are now left as a high divide (figs. 1A, B). The present-day Platte River valley system to the south and the Niobrara River Valley to the north were developed in latest Tertiary or earliest Quaternary time. The remnant deposits discussed in the present paper are confined to an area of about 10 square miles in south-central Sioux County, Nebraska, centering near latitude 42° 10' N, longitude 103° 45' W.

In the early 1900s fossils from the Sheep Creek-Snake Creek beds were considered to be representative faunas of Medial Miocene and Early Pliocene times. By mid-century the Lyellian terms for these epochs had become ambiguous; more precise terms were needed in order for paleontologists to communicate ideas of time-faunal relationships. Thus, the North American Land Mammal age applied to the Early Miocene Sheep Creek Fauna came to be latest Hemingfordian, that of the Medial Miocene Lower Snake Creek Fauna, Barstovian, and that of the Late Miocene Snake Creek Fauna, Clarendonian and Hemphillian. Future radiometric dating will provide a

specific time-scale in years for these portions of the Land Mammal Ages.

In 1908 W. D. Matthew, H. J. Cook, and Albert Thomson of the American Museum of Natural History collected the first fossils from the area. In a preliminary report of the rocks and fossils Matthew and Cook (1909, pp. 362-363) recognized two formations: A "Medial" Miocene Sheep Creek Formation (barely mentioned, with no faunal descriptions), and an undifferentiated "Pliocene" Snake Creek Formation that yielded a highly diversified collection of vertebrate fossils, many of which were new to science. Subsequent collecting and further study revealed to Matthew (1918, 1924a) that his Snake Creek Formation contained two temporally different faunas that he called Lower Snake Creek and Upper Snake Creek.

Later authors (i.e., A. L. Lugen, 1939; Elias, 1942) viewed the problem in quite a different way: they expanded the temporal concept of the Early Miocene Sheep Creek rocks containing Late Hemingfordian fossils to include lithologically unrelated rocks containing Early Barstovian fossils. A. L. Lugen (1939) gave no stratigraphic sections from which sound geologic conclusions

could be drawn, and which would have showed the complexity of the fossiliferous deposits that he included under the name Sheep Creek.

In the present report the Sheep Creek Formation is interpreted as it was introduced by Matthew and Cook (1909b), which they limited to sediments that can be defined lithologically, and not as did A. L. Lugen (1939), and Elias (1942), who expanded it to include lithologically dissimilar rocks. The Snake Creek Formation of Matthew and Cook (1909b) and Matthew (1918, 1924a) is redefined and new aspects of deposition are shown. Matthew's "Lower Snake Creek beds," which contain the Lower Snake Creek Fauna, are named Olcott Formation (New). Outcrops at Olcott Hill show the superposition of beds at the type section of the Olcott Formation and the restricted and revised Snake Creek Formation (fig. 4A). Three members of the Snake Creek Formation are recognized: The Murphy Member (New) is overlain by the Laucomer Member (New), type outcrops being on Olcott Hill; the Johnson Member (New) is recognized only in the northwest part of the area with type outcrops in East *Pliohippus* Draw (fig. 7F).

A retrospective survey of the exploration of the area presents the stratigraphic interpretations (some of which were ill-founded) of early workers and their effect on the study of Midial and Late Tertiary paleontology. Matthew's, Sinclair's, and Cook's publications of the Sheep Creek-Snake Creek beds from 1909 to 1968 reflect their failure to distinguish between rocks containing the Lower Snake Creek and the Snake Creek faunas. As a result, some Lower Snake Creek fossils (Early Barstovian) became identified with Snake Creek fossils (Clarendonian and Hemphillian). Had it not been for the misleading similarity between the Olcott and Snake Creek sediments, Matthew, Cook, and others might have been able to distinguish between the Lower Snake Creek and Snake Creek faunas, or if there had been one ideal locality where all three formations (Sheep Creek, Olcott, and Snake Creek) were in clear-cut superposition, or if the marked erosional unconformities between the formations (as do exist) had been observed, some of the confusion would have been avoided.

In the geologic part of this report, schematic diagrams (figs. 8-13) illustrate a series of cyclic events that involved Miocene sedimentary rocks

in west-central Nebraska. The diagrams are based partly on field data and partly on interpretations of the local, fluvial channel cuttings and fillings in their chronological succession. The local sedimentary history does not lend itself well to the written word, whereas geologic sections and maps offer a solution to the problem in another dimension. Quarry relationships, elevations, paleovalley walls, and paleoland surfaces based on elevational controls and stratigraphic sections are shown in detail. Maps (figs. 1-3, 15-17) show landmarks, the location and elevations of the study area and surroundings, historic and recently exploited fossil sites, locally named draws, outcrops of the formations under study, and landowners from 1908 to the present.

The systematic section deals mostly with specimens that appear in previous publications. In the case of the Snake Creek Fauna, the *Aphelops* Draw (New) Fauna and the ZX Bar (New) Local Fauna, some heretofore unpublished specimens have been listed according to their stratigraphic occurrence, but no new taxa have been named. Wherever possible the fossils have been assigned to their proper quarry sites.

Although a wide variety of taxa has been reported since the initial work of Matthew and Cook (1909b), a complete picture of the faunas cannot be shown until the major part of the collection is studied. Certain reported occurrences are interesting, however. Reptiles, amphibians, and birds are known from all three formations. Of the birds, several taxa within the Accipitriformes occurred from Hemingfordian to Hemphillian times, in addition to Psittacidae and Aramidae from the Sheep Creek Formation. The mammals far outnumber the lower orders and there is a preponderance of perissodactyls and artiodactyls. Equids make up a good share of the collection with eight genera having been reported from the three formations.

From 1908 to 1940 the American Museum and Princeton University parties, Harold J. Cook from nearby Agate, Nebraska, and the Frick Laboratory party led by Bernard J. Wilson,¹ collected at different times in the same 15 quarries, all of which are in East and West Sinclair draws (figs. 2, 15). In the course of their work, col-

¹In the Frick Archives letters and lists of fossils Bernard John Wilson is known only as "Jack" Wilson.

lectors and authors gave these 15 quarries 50 different numbers, letters, or names (sometimes all three), a factor that led to the dissipation of their faunas, mistaken locations, and displacement in geologic ages. In the present paper maps (figs. 2, 15) that show locations and synonymous names, quarry discussions, and stratigraphic sections (figs. 4-7) help to unravel this tangled nomenclature. The faunal sites discovered since 1908 have also been mapped, illustrated on geologic sections, and placed in temporal succession based on rock sequence (fig. 14).

Annual reports, letters, diaries, field lists, and photographs from the archives of the Department of Vertebrate Paleontology, the Cook and Frick collections (all in the American Museum of Natural History), and at Princeton University, have added immeasurably to the documentary data included here, thus greatly enhancing the usefulness of the geographic and stratigraphic records of the major collectors, Dr. Harold J. Cook, Dr. A. C. Whitford, and Messrs. Albert Thomson, B. J. Wilson, and M. F. Skinner.

An intimate knowledge of the faunas and the fossil-bearing sediments have been of utmost value to Skinner, who has collated data over the past 35 years; equally valuable has been his close relationship with most of the workers in the area. Dr. and Mrs. Harold J. Cook were lifelong friends; Dr. A. C. Whitford was principal of the Ainsworth, Nebraska High School during his attendance. Dr. A. L. Lugin, at the University of Nebraska, was his professor of geology and Dr. M. K. Elias was a valued colleague. Mr. George Stoll, who worked with Whitford in 1916, was a friend for many years; Mr. Albert Thomson was chief preparator in the Department of Vertebrate Paleontology, the American Museum of Natural History, at the same time that Skinner worked in the Frick Laboratory; Mr. B. J. Wilson was a field colleague, and Wilson's assistants, Messrs. Arnold Martin and Richard Jenkins, showed Skinner detailed collecting areas, supplied quarry names, and other valuable information.

ACKNOWLEDGMENTS

Mr. Childs Frick sent the first party into the Sheep Creek-Snake Creek area in 1932. From then until his death in 1965 his interest and encouragement kept research on the "Sioux

County Project" viable although work was often suspended and progress was slow. Our thanks are due Dr. Richard H. Tedford whose guidance and assistance in all parts of the work helped to bring this report to its finish. Dr. Tedford not only guided us through the biochronology, but also provided the systematics for the Carnivora. Dr. Malcolm C. McKenna was one of the first to urge that work on the present paper be continued and made many helpful suggestions to improve the presentation. Dr. Bobb Schaeffer generously provided us with facilities to carry on research and writing. Mr. Beryl Taylor gave of his time and extensive knowledge of the Tylopoda and Ruminantia, and provided the systematics for these groups. Mr. Ted Galusha critically read the manuscript in the first draft and discussed most of the geologic problems with us throughout the course of the work. Mr. F. Walker Johnson also read the manuscript and checked in detail the geographic locations. We are deeply indebted and grateful to these people, but none can be held responsible for any errors that we have made in presenting the data.

Mr. George Krochak has given assistance in searching specimen lists, Mr. Ernst Heying has been helpful in preparing fossils needed for comparison, and Mr. Otto Simonis has been cooperative whenever needed. Ms. Charlotte Holton provided us with library assistance and Ms. Barbara Werscheck has been invariably helpful in expediting our transitions to and from the field.

Dr. Robert J. Emry, National Museum of Natural History, Smithsonian Institution gave invaluable suggestions in the preparation of the manuscript and made a brief reconnaissance over the area with the senior author. Ms. Pat Vickers Rich, The Museum, Texas Tech University at Lubbock, gave us valuable and much needed advice on the birds from the study area.

The late Dr. Glenn L. Jepsen, Princeton University, lent us the 1914 diary and photographs of Dr. W. J. Sinclair without which some of the history of the Princeton Expedition to Sioux County could not have been presented here.

From 1941 through 1947 several people assisted us in field work in the area. Two have died: Messrs. Arnold Martin and Ove C. Kaisen. Others were: John Beattie, M. D., Messrs. Gordon Fletcher and William Laverty, William Lear, M. D., Thomas Lucas, M. D., Mr. Leonard

Nelson, and Morris F. Skinner, Jr., M. D. We are greatly indebted to these men.

Throughout field work in the Sioux County area we have received many courtesies from residents of the area who permitted us access through their pastures to quarry sites. We are most grateful to the late Messrs. Charles Laucomer and Clarence Kilpatrick. We have been courteously given access to the valuable grazing lands by Mr. and Mrs. Vance Johnson, Mr. and Mrs. Stephen Johnson, Mr. and Mrs. David Laucomer, and Mr. and Mrs. James Murphy.

ABBREVIATIONS

AMNH, the American Museum of Natural History

ANSP, Academy of Natural Sciences of Philadelphia

CMNH, Colorado Museum of Natural History

F:AM, Frick American Mammals, the American Museum of Natural History

HC, Harold Cook Collection

K/A or K-Ar, Potassium Argon

PU, Princeton University

SDSM, South Dakota School of Mines

UCMP, University of California, Museum of Paleontology

USC & GS, United States Coastal and Geodetic Survey

USGS, United States Geological Survey

USNM, National Museum of Natural History, Smithsonian Institution

LOCATION AND EXTENT OF THE AREA

Figures 1-3, 17

The Sheep Creek-Snake Creek fossil deposits lie within an area of about 10 square miles on the high plains of south-central Sioux County, Nebraska. Included in the area are townships 25 and 26 N, range 55 W. The county seat, Harrison, which is about 36 miles north, was served by the Chicago and Northwestern Railway in the early 1900s and was a disembarkment point for early collectors. Agate, also a reference point for many paleontologists because of the nearby Agate Springs fossil quarries, was an inland ranch post office on the Niobrara River, 22 miles south of Harrison on Nebraska State Highway 29 and 16 miles north of the Sheep Creek-Snake Creek area. Most early records give the trail distance to the Sheep Creek-Snake Creek area as 23 miles south of Agate. In 1964 the Agate Fossil Beds National Monument was established east of the Agate post office, and on November 30, 1968 the post office was closed. In the 1920s other ranch post offices in the south-central part of Sioux County were Andrews, Ashbrook, Canton, Curly, and Aldine; none are extant.

North-south state highways 29 to the west and 71 to the east bracket the Sheep Creek-Snake Creek area. Access to the fossil deposits, however, is over privately owned ranchlands. Mr.

David Laucomer owns the southernmost part of the area, Mr. James Murphy the north-central part, and Mr. Vance Johnson the west and northernmost parts (fig. 17). Most of the land is covered by typical high plains short grasses used for grazing cattle and horses.

The area lies on the Platte River side of the divide between the Niobrara and Platte rivers (fig. 1B), in the southwestern part of the Box Butte Table. Scattered grassed-over sand dunes to the north, west, and east mantle the area surrounding the fossiliferous outcrops and effectively limit the observable lithic extension of the Sheep Creek-Snake Creek sediments. One of the highest sand dunes (elev. 5020 feet) in the state lies directly west of the area at the head of Dry Spotted Tail Creek.

Matthew's and Cook's (1909b, pp. 362-363) use of the names Sheep Creek and Snake Creek for the fossiliferous deposits was not based on surface drainages within the area; the Sheep Creek and Snake Creek lie outside the designated area. On the west side, all draws west of, and including Stonehouse Draw (fig. 2) drain into Dry Spotted Tail Creek. The Sinclair draws drain into a basin closed by wind erosion, about 3 miles south of Olcott Hill in the N $\frac{1}{2}$, sect. 26, T. 25 N, R. 55W, Sioux County, Nebraska, which is indirectly a part of the Spotted Tail Creek drain-

age. Antelope and Ranch House draws, north of Olcott Hill, are at the heads of a set of drainages leading into another closed basin 3 miles east that has been separated by dune sand from the head of Snake Creek some 5 miles farther east. The American Museum and Frick Laboratory field parties named the local draws (fig. 2) primarily for their own identification. Matthew (1924a, p. 63, fig. 1) published the names of the various draws and localities that had been used by the American Museum collectors: viz., West, *Aphelops*, *Merychippus*, East and West *Pliohippus*, Stonehouse, East, West and Sinclair draws and Olcott Hill. In the 1930s Wilson named Ranch House and Antelope draws, but otherwise followed Matthew's (1924a) nomenclature.

METHOD OF ELEVATION CONTROL

Figure 1B

In 1941 the Skinner field party established a temporary bench mark in front of camp headquarters in Antelope Draw (fig. 2) by driving a Ford Model A axle into the ground. This site is on the west-central side of the SW $\frac{1}{4}$, SE $\frac{1}{4}$, NE $\frac{1}{4}$, SE $\frac{1}{4}$, sect. 33, T. 26 N, R. 55 W, Sioux County, Nebraska. In the same year a more easily located and lasting object was selected as a reference bench mark with a local base elevation of zero. This is the top of a concrete slab surrounding the casing of a well in the yard of the former Kilpatrick ranch house in the southeast corner of the NE $\frac{1}{4}$, NE $\frac{1}{4}$, SE $\frac{1}{4}$, SW $\frac{1}{4}$, sect. 34, T. 26 N, R. 55 W. In Skinner's field notes this is referred to as the "ranch house bench mark." The buildings have now (1977) been removed, but the well, windmill, and concrete slab remain in the corrals of the present owner, James Murphy (fig. 17).

In 1967 Skinner's system of elevations was referred to and correlated with the 1934 USC & GS bench-mark tablet Q-58, thus making it possible to use standard elevations above sea level in regional comparisons. Starting from the 1946 survey bench mark 27, the highest point on top of a hill on the east side and near the head of *Aphelops* Draw (fig. 2), a line of sights was carried forward that united Skinner's 1941 and 1946 surveys with the USC & GS bench-mark

tablet Q-58 (elev. 4968.8 feet) in the northeast corner of section 24, T. 26 N, R. 56 W, on the west side of Nebraska Highway 29 as it was in 1934 (part of this highway has since been re-routed east of the section line).

By correlating the ranch house bench mark with the elevation of USC & GS bench-mark tablet Q-58, the elevation of the ranch house bench mark was determined as 4755 feet and this correction was applied to the 1941 and 1946 elevations. The next closest bench-mark tablet, R-58, could not be found, perhaps having been destroyed by road work. It is recorded, however, as being near the northeast corner of sect. 36, T. 26 N, T. 55 W. The ground elevation near the given site of bench mark R-58 checked our system within 3½ feet, which is well within the accuracy required for this study.

Fence lines that have been established for many years and aerial photographs were used to plot section lines as closely as possible from established section corners. When topographic sheets are made of this area, the elevations that were established in 1941, 1946, and 1967 may not coincide exactly with mapped intervals, but quarry and stratigraphic elevations will be consistent within our survey system.

The instruments used were a plane table, telescopic alidade, and a Locke level for stratigraphic sections.

MAPS USED FOR DRAINAGES AND QUARRY SITES

We began mapping in the field in 1942 by plotting quarries and other information on the 1939-1940 uncontrolled aerial photographic mosaics of Sioux County. The only topographic map available, then as now, was the United States Geological Survey Whistle Creek Quadrangle for 1899 (surveyed in 1895), which has a contour interval of 20 feet.

United States Coastal and Geodetic Survey bench marks along the 1934 route of Nebraska Highway 29 (present route altered) show the errors in elevations on this quadrangle (table 1). In an area comprising T. 25 N, R. 55 W, the 4800 foot contour is mislabeled "4700." Elsewhere, "4600" is incorrectly placed on the 4700 foot contour, this being in that part of the map used by Thomson (fig. 16) and published by Matthew

TABLE 1
 Errors in Elevations on Whistle Creek Quadrangle, 1895 United States Geological Survey
 Compared with United States Coastal and Geodetic Survey Bench Marks of the 1934
 2d Order Survey
 (Elevations in Feet)

C & GS Bench Marks	Location	Whistle Creek Quadrangle	USC & GS 1934	Elevational Error
L-58	SE corner sect. 19, T. 27 N, R. 55 W	4860	4778.8	+81.2
M-58	SE corner sect. 30, T. 27 N, R. 55 W	4815	4803.5	+11.5
N-58	NW corner sect. 5, T. 26 N, R. 55 W	4820	4769.0	+51.0
P-58	NE corner sect. 12, T. 26 N, R. 56 W (Tower Hill section tied to this bench mark)	4840	4845.4	- 5.4
Q-58	NE corner sect. 24, T. 26 N, R. 56 W (Skinner survey tied to this bench mark)	5000	4968.8	+31.2
R-58	NE corner sect. 36, T. 26 N, R. 56 W (could not locate bench mark)	4900	4872.9	+27.2

(1924a, fig. 1). Matthew noted that the map was inaccurate, but did not identify it as a United States Geological Survey Quadrangle and Osborn (1936, fig. 392) corrected the contour lines on the part he published; the corrected contour intervals and slightly larger scale gave more details than had been published previously. Thomson's (fig. 16) undated map was made after the discovery of Kilpatrick Quarry (post-1926), but supplied valuable data for his quarry names that have not been found elsewhere. This map, which is in the Department of Vertebrate Paleontology Archives in the American Museum, and that published by Matthew (1924a, fig. 1) apparently were the source of Osborn's (1936, fig. 392) map.

Although the inaccuracy of the Whistle Creek Quadrangle was well established in the literature, it was the main source of locality data. Beside the obvious drawback of incorrect contours, the small scale of the Whistle Creek Quadrangle did not allow accurate designation of the draws that contain fossiliferous deposits. Earlier workers were fortunate if they could locate quarry sites within the square mile. Sinclair (1915) was the only one of the early Sheep Creek-Snake Creek

authors who gave geographic locations, and he also used the Whistle Creek Quadrangle, misplacing *Aphelops* and *Merychippus* draws in section 31. Sinclair gave Locality 1000A as the NE $\frac{1}{4}$, sect. 31, T. 26 N, R. 55 W. Sinclair's (MS) photographs of Locality 1000A, however, show outcrops that can only be identified as near the head of *Aphelops* Draw in the NE $\frac{1}{4}$, sect. 30, T. 26 N, R. 55 W.

The base map (fig. 2) showing drainages and quarry sites was made directly on the 1939-1940 uncontrolled aerial photographic mosaics (4 inches to the mile) of Sioux County, Nebraska, by the United States Department of Agriculture, Agricultural Adjustment Administration. The offset shown on the line between townships 25 and 26 is due to optical distortion along the edges of two sheets of the 1939-1940 uncontrolled mosaics.

When the 1954 aerial photographs (8 inches to the mile) by the United States Department of Agriculture, Agricultural Stabilization and Conservation Service became available we used these photographs (north half, 7-3-54, CBE 7-N, 130, 132, 134, and south half, 7-3-54, CBE 7-N, 168, 169, 171) to locate the quarry sites in greatest

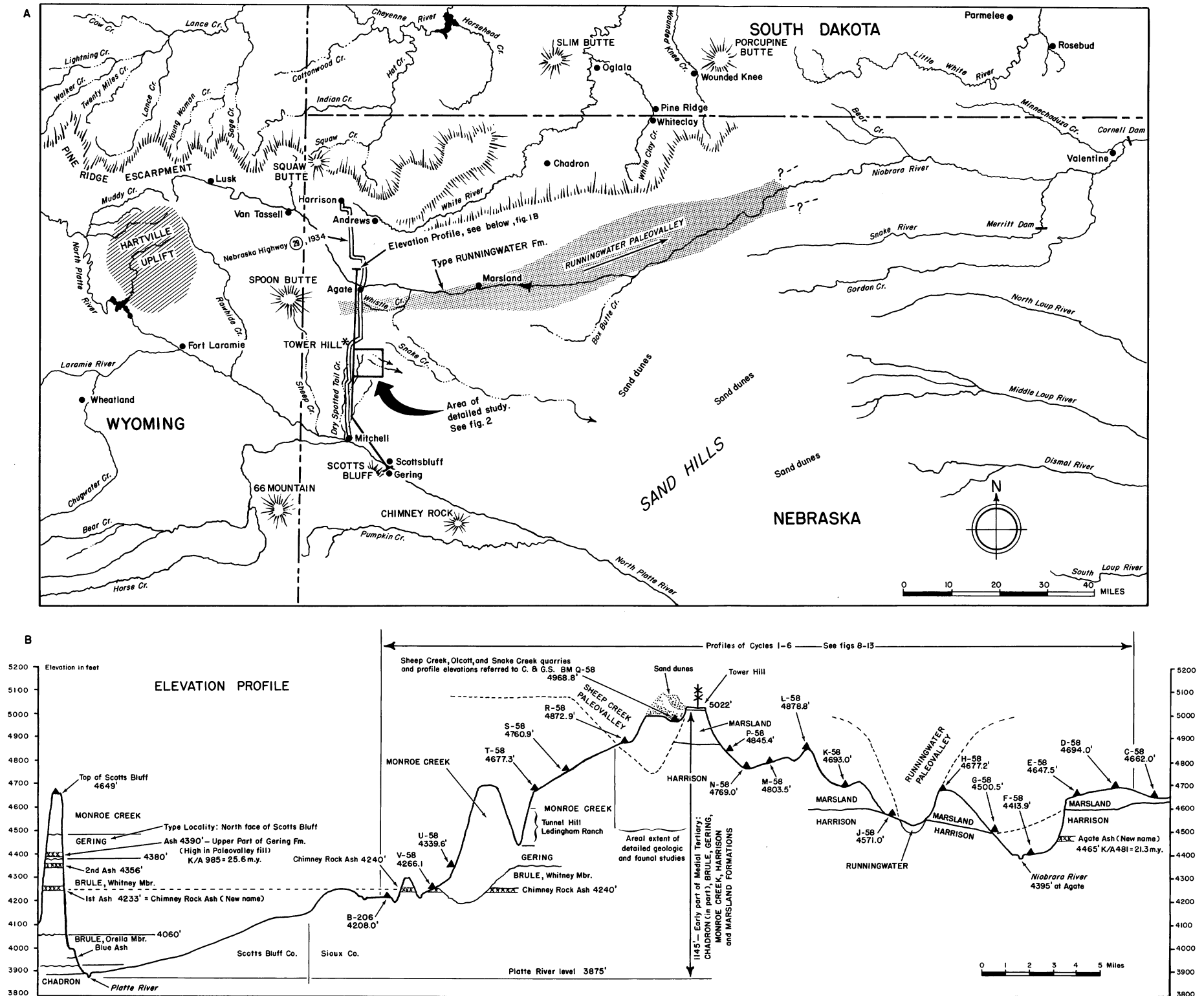


FIG. 1. A. Index map of western Nebraska, eastern Wyoming, and southern South Dakota, showing relation of Sheep Creek-Snake Creek area to regional geography. B. Elevational profile from Scott's Bluff and Platte River valley to Niobrara River valley at Agate, Nebraska, in relation to Sheep Creek-Snake Creek area.

possible detail, and transferred them to the base map (fig. 2). By the time the 1961 aerial photographs (same data as for 1954) became available our mapping had been completed. We used the 1961 photographs only as a check of the two previous sets.

The three sets of flight sheets (1939-1940, 1954, 1961) show the changes and additions in ownership and fence lines, quarry work, and landmarks (e.g., bomb target, windmills, army barracks) that were all a part of locating quarry sites on the base map (fig. 2). The 1954 flight was made closest to the time that Wilson's and Skinner's quarries were excavated, the army barracks and bomb targets were still visible, and fence and ownership lines had been corrected or resurveyed. The 1961 flight shows the drainage patterns clearly, but by that time some of the

quarries had grassed over, slumped down, or had been filled according to landowners' requests. Today many of the early excavations have been obliterated.

United States Geological Survey Transverse Mercator Projection Alliance (1955) and Scottsbluff, Nebraska (1956) have contour intervals of 100 feet with supplementary contours at 50 foot intervals. These intervals are too great and the map scale is too small to provide the details that were necessary for the present report.

General Highway Map, Sioux County, Nebraska (1960), prepared by the Department of Roads, Program and Planning Section, has a scale of 1 inch to the mile. This map combined with the aerial photographs gave us the sections, townships, and ranges.

HISTORICAL REVIEW

THE 1908 AMERICAN MUSEUM OF NATURAL HISTORY EXPEDITION

Exploration of the Sheep Creek-Snake Creek area started in the summer of 1908 as an unscheduled prospecting trip for W. D. Matthew and his American Museum party, whose real purpose was to collect in the famous Agate Springs quarries, which were at that time the most exciting and prolific quarries in North America. Along with the American Museum party were collectors from Carnegie Museum, Yale College, Amherst College, and Nebraska State Museum, all eager to work the thick bone layers for remains of the sickle-clawed *Moropus*, the giant pig, *Dinohyus*, and the double-horned rhinoceros, *Diceratherium*. Good-natured rivalry developed among the contenders from these five institutions but W. J. Holland of Carnegie Museum took a more aggressive stand and claimed exclusive rights to the main quarry on Carnegie Hill, a position that left the mild-mannered Matthew little choice but to prospect elsewhere.

The first news of fossils in the Sheep Creek-Snake Creek area was brought to Harold Cook at Agate in June 1908 by a chuck-wagon cook from the Olcott ranch 20 miles south. In a letter to Osborn at the American Museum, Matthew (June

25, 1908) wrote: "Next week I hope to make a trip south to the head of Snake Creek, and look into the exposures there and at Spoon Buttes, and from there we may go on to the breaks north of the Platte. This country is not played out by any means, but with the Nebraska, Amherst, and Yale parties here in addition to the Carnegie, it is too crowded, and our staying on here in the present uncertain status of things puts us in a rather unpleasant position in certain ways, and adds to the friction with the Carnegie outfit, which I don't wish to do."

After his trip, Matthew wrote to Osborn on July 3, 1908: "Harold Cook and I have just returned from a trip to the head of Snake Cr'k, twenty miles south of here. We have obtained some interesting material and identified two new faunas for this section, one Middle Miocene, characterized by *Merychippus* and other genera, the other Pliocene-early Pliocene, characterized by a large fauna like that of the latest Miocene but more specialized and with abundant Camels of gigantic size some or all *Pliauchenia*, very abundant and varied horses of the *Protohippus* group, *Teleoceras* and *Peraceras*, *Aelurodon* and other carnivora, *Mylagaulus*, *Mastodon*, and so on. No *Equus* . . . Harold and I collected 710

complete horse teeth in a couple of days work besides 35 big camel astragali . . . A considerable part of the fauna will be new—at least two new genera, a raccoon related to *Bassariscus* and a Bovid! with perfectly straight horn somewhat oval in cross-section. We have provisionally called these beds Snake Creek beds . . . The Snake Creek material is in loose sand or only slightly consolidated, and the bone extremely hard and solid.

"The Middle Miocene will give us associated material, pretty soft, but easily worked out, and I think is mostly specifically distinct from the Pawnee Creek fauna although roughly equivalent. [Specimens from these beds were listed under 'Sheep Creek beds, provisional list of fauna.']

"I am anxious to avoid any word of these new faunae getting out at present, as the known exposures are quite limited and I don't want any of the other expeditions to get into them until we are through with them."

Matthew, Cook, Thomson, and field assistants William Stein and Roy Moodie made a second trip to the area. Subsequent letters gave details of their progress. In a letter of July 18, 1908, Matthew wrote to Osborn: "We have put in nearly a week on the Pliocene beds . . . have a large series of jaws and parts of jaws and several thousand teeth, but I'm sorry to say no skulls. The horses—probably a dozen species, all *Protohippinae*—are the greater part of the collection, but some forty species are distinguishable altogether. We have quarried at three localities on different levels and obtained apparently three different phases of the fauna, which may be successive, or merely contemporary facies.

"We have failed to find any further extension of this deposit beyond the three or four miles along which it lies from east-southeast to west-northwest. My hypothesis about it is, that it is a residual channel deposit, left from a soft sand formation which has been destroyed since Pliocene time by wind and water erosion, the gravel in the channel beds serving to protect them. The material is mostly waterworn and windworn, but now and then specimens occur in fine preservation . . . it is now a question of how much further work is worth while. The same amount . . . on Lower Miocene would turn out much more complete material, but with less novelty to it. So

far, we have but one associated specimen, a skull, jaws, limb and footbones and vertebrae of a large camel, tibia abt 2 ft. 4 in. long." On July 25, 1908, Matthew wrote Osborn that he was leaving for the east: "We have pretty well rounded up the pocket south of here, and unless we can locate other exposures will be through with it in a week or two. We have in addition to what I reported in my last a skull of a gigantic camel out of the Pliocene, a number of incomplete skeletons of *Merychippus* out of the Miocene and . . . about 6000 to 7000 horse teeth."

The discovery of the large and varied "Pliocene" fauna, older than the Blanco of Texas, was of great significance for it seemed to fill part of the gap between "late Miocene and middle Pliocene" faunas. A decade would pass before Matthew and Osborn realized that there were three "Pliocene" faunas: one Barstovian, the others Clarendonian and Hemphillian. Osborn (in lett. July 28, 1908) answered Matthew: "I am very much interested in the results of your work in the Pliocene beds, especially in your extensive collection of horses. This will probably give us an exceptionally clear idea of the varieties of horses existing at one time and in one region . . . I do hope we shall secure a Lower Miocene horse, mountable; also a Middle Miocene horse, mountable. When you think of it, those two stages and the Upper Miocene *Protohippus* [*sic*] type are what are chiefly needed to complete our evolutionary series."

Among the more novel fossils that Matthew and Cook (1909b, p. 413) reported was a bovid, *Neotragocerus improvisus*. This specimen, and some peccary teeth, which resembled those of anthropoids, later became the subject of a long-lasting dispute on the presence of early man in the Snake Creek beds. Expectation of finding an anthropoid was also a factor in the continued exploration of the Snake Creek beds in the 1920s. Matthew and Cook (1909b, p. 390) stated: "The anterior molars and premolars of this genus [*Prosthennops*] show a startling resemblance to the teeth of Anthropoidea . . . It should nevertheless be pointed out that the improbability of finding Anthropoid teeth in a Lower Pliocene formation in this country is substantially decreased by the discovery of true antelopes at this horizon. The antelopes of the

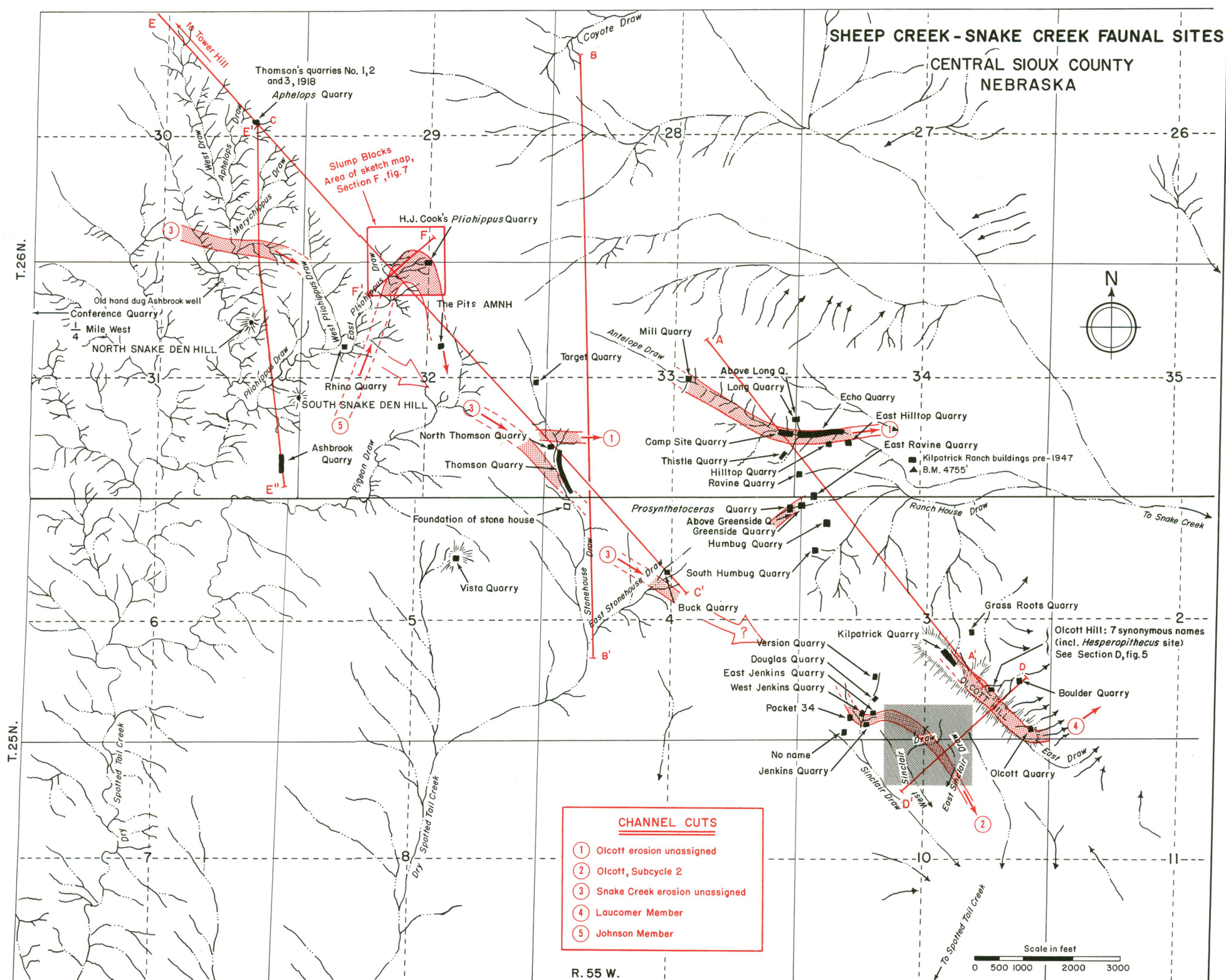


FIG. 2. Miocene faunal sites showing (in red) channel cuts of Olcott and Snake Creek formations, slump block area (see fig. 6E), and (in black) the Sinclair draws (see fig. 15).

Snake Creek beds belong to the Tragocerine group which are found associated with extinct Anthropoidea in the Upper Miocene and Pliocene of Europe."

COOK'S WORK FROM 1908 TO 1962

For five or six years after their discovery the Sheep Creek-Snake Creek beds were virtually untouched except for the few specimens that Harold Cook collected. (From 1911 through 1914 Albert Thomson collected at the Agate Springs fossil quarries for the American Museum.) Fossil collecting was a tradition in the Cook family and Cook's (MS) catalogue shows that much of his early collecting was done with his brother, John, and later with his wife, Margaret, on weekends, or at any time he had free from ranch duties at Agate. Paleontologists from museums in the United States, Canada, and Europe visited Cook at Agate and consulted him on the fossils and geology of the Sheep Creek-Snake Creek beds.

In Cook's (MS) catalogue and publications he frequently referred fossils to three of his prospecting sites: *Mesoceras thomsoni* locality (West Sinclair Draw, fig. 15), *Pliohippus* Quarry (East *Pliohippus* Draw, fig. 2), and the *Hesperopithecus* site on Olcott Hill (fig. 5D). Although Matthew (1924a) treated the sediments in the Sinclair draws informally as the Lower Snake Creek beds—a phase of the Snake Creek Formation-Cook (MS), as late as July 4, 1962, referred to these same sediments as the "Snake Creek Beds." The last specimens that Cook catalogued were under entries HC 1331 (=AMNH 83389) to HC 1335 (=AMNH 82593), for which he gave the data: "Sinclair Draw, Snake Creek Beds, same level and spot as where I found *Mesoceras Thomsoni*, Type." As early as 1922, however, Cook realized that part of his "Snake Creek" fauna was older (the lower Snake Creek Fauna) than the faunas from Olcott Hill (Snake Creek Fauna) and from the northwestern part of the area (ZX Bar Local Fauna), but he held firmly to his belief that the unconsolidated fluvial deposits were one lithic unit—the Snake Creek beds.

Cook's collection is notable, containing more than 1350 catalogued specimens, among which

are at least 35 type specimens. A large part of the collection is unstudied, but all of it reflects Cook's unflagging interest in fossils, particularly those in the Sheep Creek-Snake Creek beds.

Cook's 1916 collection is noteworthy because of his discovery of a skeleton of *Dinohippus leidyani* (Osborn, 1918) from East *Pliohippus* Draw. Matthew to Osborn (July 17, 1916) wrote: "the *Pliohippus* skeleton . . . is a big one-toed advanced species of this genus, pretty near I should say to Merriam's tooth [*P. proversus*] and carrying throughout the intermediate characters between P. & E. [*Pliohippus* and *Equus*] indicated in his type." At the time of this discovery Cook was collecting independently from an American Museum party that was in the area headed by Whitford. Matthew arranged the transfer of this specimen to the American Museum of Natural History.

THE 1914 PRINCETON UNIVERSITY EXPEDITION

In May, 1914, W. J. Sinclair sent A. C. Whitford and Charles Barner to the Sheep Creek-Snake Creek area where he later joined them. Whitford's first camp was on the south side of *Aphelops* Draw above the exposures of volcanic ash in the Sheep Creek Formation (figs. 2, 6E). Sinclair (1915, p. 74) named this Locality 1000A. Sinclair's (MS) field notes and photographs, and Whitford's (MS.a) field notes supplied most of the locality data for the Princeton 1914 expedition reported in the present paper.

On May 12, Whitford and Barner moved their camp 2 miles east. No photographs of the second camp have been found, but Whitford's (MS.a) description indicates that it was either at the head of Antelope Draw or in the drainage north of it (fig. 2). Sinclair's (1915, p. 74) geographic description of Locality 1000B fits this drainage. Sinclair (1915, p. 86) described a lower premolar (PU 12128) that he referred to *Archaeohippus* sp., and gave Locality 1000B as the provenance. That locality included any site in the designated quarter section. In Sioux County *Archaeohippus* has been found only in the Sheep Creek Formation, and this formation is present in the quarter section that Sinclair designated for Locality 1000B.

Whitford was probably familiar with Matthew's description of the "Snake Creek Beds" and the photograph in Osborn's (1910, fig. 162) Age of Mammals. In any event, Whitford's third camp was in the area of the photograph in what is now called East and West Sinclair draws, both having sedimentary rocks of Early Barstovian age. The third camp was at the head of West Sinclair Draw (fig. 15) that Sinclair (1915, p. 74) included in Locality 1000C. Sinclair also included in this locality East Sinclair Draw, and the younger Early Clarendonian channel deposit on the crest of Olcott Hill, $\frac{1}{2}$ of a mile northeast of West Sinclair Draw (fig. 5D).

According to Sinclair (MS) Cook brought him to the third camp on June 13, after having shown him the local geology as interpreted by Matthew and Cook (1909b), for Sinclair (1915) had the same concept of a Miocene Sheep Creek Formation overlain by "early Pliocene" Snake Creek beds. Following these authors, Sinclair made no distinction between the lithically different channel deposits on top of Olcott Hill (restricted Snake Creek Formation, present paper, p. 306) and the Barstovian deposits (Olcott Formation) of the Sinclair draws that were also called Snake Creek by Matthew and Cook (1909) and later by Matthew (1924a).

The channel deposits in the Sinclair draws and on top of Olcott Hill are not only close together, but they have a similar color and sandy texture that deceived Matthew, Cook, and Sinclair. The result of this has been that, in the literature, the Barstovian Lower Snake Creek Fauna has been confused with the Clarendonian Snake Creek Fauna (fig. 5D), the Early Hemphillian *Aphelops* Draw Fauna, and the Late Hemphillian ZX Bar Local Fauna (fig. 7F).

WHITFORD'S WORK FOR THE AMERICAN MUSEUM OF NATURAL HISTORY IN 1916

In July, 1916, Whitford and his assistant, George Stoll, began work in the Sheep Creek-Snake Creek area under the direction of Albert Thomson, who was working at Agate Springs Quarry. Whitford and Stoll established their camp near West Sinclair Draw (figs. 2, 15) in the same area where Whitford had successfully col-

lected for Princeton in 1914. Whitford (MS.b), in his description of their principal collecting area, gave the wrong section and range. Elsewhere in the same report, Whitford mentioned the generalized section and a geographic description that fits Princeton's 1914 Locality 1000C (i.e., the head of West Sinclair Draw and Olcott Hill).

In a preliminary summary of the 1916 collection Matthew (1918, p. 185) again referred to the possibility of fossil anthropoids: "Although I have not listed fossil anthropoids as part of the fauna, it may be well to repeat that certain isolated teeth in the collection, provisionally referred to *Prosthennops*, are singularly like those of anthropoid apes." Nothing else was published about this but speculation must have been rife about the possibility of such a find.

Matthew (1918, p. 184) reporting on the 1916 Sheep Creek-Snake Creek collection mentioned that Merriam's work in later Tertiary faunas of the Pacific Coast had "afforded evidence . . . that the Snake Creek fauna might in fact be a composite and not all of the same age." Matthew (1918, p. 184) also expressed concern about the "records and observations of the subsequent [1916] collecting" not being "exact enough to clear up this doubt; but there seems to be some reason to believe that different fossiliferous pockets may be of different ages, ranging from late Miocene to early Pliocene."

Matthew's concern about the 1916 collection may have been justified. Thomson's letters to Matthew, and Matthew's letters to Osborn, indicate that there was a lack of cooperation among the men in the field. Whitford returned early in September to the American Museum and Stoll was dismissed. Thomson (MS.b) wrote: "They [Whitford and Stoll] succeeded in securing a fairly good collection from the Snake Creek beds though badly collected . . . Before sending in Mr. Whitford's Snake Creek collection I unwrapped every package and thoroughly shellaced [*sic*] every bone to insure the collection's safe arrival at the Museum." The repacking was done at the request of Osborn who visited the area late in September after Whitford and Stoll were gone. According to Skinner's communications in the 1950s with Stoll, Whitford sent lists to Osborn that were made up as they packed specimens. These lists or any record of them have not been

found. Thomson, expert field man though he was, could not have given locational data as he repacked without having some previously made lists: so, if lists were used later when the specimens were unpacked, errors in collecting data would merely have been repeated.

THE 1918 TO 1927 AMERICAN MUSEUM OF NATURAL HISTORY EXPEDITIONS

Field work was almost suspended in 1917 because of the uncertainty of the entry of the United States into World War I and the effect it would have on the affairs of the staff.

Thomson's (MS.c) 1918 field list shows that only a few specimens were collected, 10 from Quarry 1 in *Aphelops* Draw, another from near there, and a small collection from Sinclair Draw.

After two seasons (1919, 1920) spent at the Agate Springs Quarry, Thomson resumed collecting in 1921 in East and West Sinclair draws (figs. 2, 15). Three important quarries that he named and worked that year are in East Sinclair Draw in the Olcott Formation (New): Quarries A, B, and the Sheep Creek Channel Bed. In the present paper Quarry A is East Surface Quarry, B is Camel Quarry, and the Sheep Creek Channel Bed is Trojan Quarry (fig. 15). Thomson's name for the Sheep Creek Channel Bed Quarry was unfortunate, as it naturally led researchers to believe that it was in the Sheep Creek Formation. Thomson's (MS.d) statement that mostly escaped notice was clear: "a fifth quarry . . . we called the Sheep Creek Quarry, because it is a channel bed cut down into the Sheep Creek beds. Though material . . . seems to be the same as in quarry A & B."

The 1922 letters, publications, and field work reflected the excitement surrounding the discovery of "anthropoid fossil man." In February Cook sent Osborn a fossil molar that he had found on top of Olcott Hill in the Snake Creek Formation (see Laucomer Member, New, of Clarendonian age, p. 310). Osborn (April 25, 1922) published a short notice that the first anthropoid primate had been found in America, to which he gave the name *Hesperopithecus haroldcookii*. Thomson's plans to spend the summer of 1922 looking for more complete evidence of the anthropoid went awry when Ashbrook, the

owner of the *Hesperopithecus* site, refused access to his land. On June 18, 1922 Thomson wrote to Osborn, "I am going to try again . . . to see Mr. Ashbrook and offer to purchase 30 or 40 acres of the ground and then fence it . . . this being the spot where *Hesperopithecus* was first found;" to which Osborn (in lett. June 27, 1922) replied: "I am deeply interested to learn that the *Hesperopithecus* tooth came from this spot, because it is certainly sacred ground . . . This animal will have a remarkable skull, and heaven grant that you may secure a bit of it."

In spite of the interest that the discovery of "*Hesperopithecus*" had roused, Matthew remained cautious; on July 9, 1922, he wrote from Agate advising Osborn: "You cannot solve the geologic and paleontologic problems that centre around the *Hesperopithecus* without making a systematic broad study of the whole series of formations here from the White River up."

Meanwhile, the scientific world reacted with doubt because of the meager evidence of one tooth. Five years later Gregory (1927, p. 580) gave an account of the publications that had related to Osborn's new primate genus: "Many authorities made the objection 'Not proven,' which is raised to nearly every striking new discovery or theory." Gregory went on to explain that the much worn type molar was "strikingly similar . . . to one of the upper molar teeth that had been found . . . near the famous skull top of *Pithecanthropus erectus*."

Gregory and Hellman (1923a), in their analyses of the characters of the "*Hesperopithecus*" molar, had compared it with chimpanzee and American Indian. Further comparisons led Gregory and Hellman (1923b) to conclude that "the specimen could not represent a lower molar of any carnivore, that none of the other suggestions as to its possible relationships had proved tenable, that the greater number of resemblances of the type appeared to be with the gorilla and the chimpanzee rather than with the orang."

One other event during the summer of 1922 that would insure continued investigation of the area was a visit by Mr. and Mrs. Childs Frick. In the company of Matthew and Cook, Mr. and Mrs. Frick made a reconnaissance trip across the Tertiary section between Hat Creek, Nebraska, and Pawnee Buttes, Colorado. The Sheep Creek-

Snake Creek beds lay between these two areas. In anticipation of this visit Matthew (June 20, 1922) wrote to Thomson: "He [Frick] wants to see something of the Tertiary beds . . . We don't of course, expect to find much new in so short a trip. But I may say that he [Frick] has placed \$3000 extra to our credit for paleontological field work . . . We are not cramped for funds this year . . . New experience for me." From 1932 until today, Frick funds have been available for collecting and research in the Sheep Creek-Snake Creek beds, and an additional 37,000 Frick specimens have been added to the American Museum and Cook collections.

In 1923 the Museum party headed by Thomson spent the summer collecting in the Snake Creek beds, always hoping that a skull, or at least a jaw of "*Hesperopithecus*" would be found. For a year other work took precedence, so it was not until 1925 that plans for the Museum party included a brief stopover at the Snake Creek beds before going on west to Goshen Hole, Wyoming for the summer. Thomson and his assistants had just begun work when Cook arrived with his guest, Prof. Othenio Abel, from the University of Vienna, Austria. Thomson (MS.g) wrote to Osborn: "We went over to the famous *Hesperopithecus* locality. Dr. Abel was fortunate to pick up a very beautiful *Hesperopithecus* upper molar. This find has stirred me up to a point that I feel it is necessary to put in one more season right here in the Snake Creek beds." During June and July 1925 telegrams between New York and Agate announced the arrivals of Osborn and Barnum Brown, their departure after decisions had been made on the best way to work the quarries, and most of all the best way to approach Ashbrook, who steadfastly refused them access to the "*Hesperopithecus*" site.

Thomson (MS.g) wrote Barnum Brown from "Camp Monkey Hill" (i.e., Olcott Hill): "We discovered yesterday, evidence of early man. We found a small instrument fossil bone . . . shaped something like this [illustration of a flat, spatulate-shaped bone] with a hole from one side running through to the end. It is about three inches in length and a little less than one half inch through the center. Then quite a large piece of . . . camel tibia which has been hacked with

some more or less blunt instrument . . . the other thing must have been used as a trowel or paddle . . . We have another dozen 'monk' teeth already."

In 1926 Thomson (MS.h) worked mainly in Grass Roots Quarry (figs. 2, 4A), which they soon exhausted, and in Kilpatrick Quarry (figs. 2, 4A), where they had previously found material that resembled artifacts and the "*Hesperopithecus*" teeth.

In 1927 Thomson's seventh and final season in the area, he and his assistants collected "bone tools" from Kilpatrick Quarry, and sent a large number to the Museum. Nels C. Nelson, an anthropologist, identified the "tools" as waterworn bones. Thomson (MS.j) admitted "to having been a little jarred" by Nelson's identification, and in his final report stated: "[We] collected only a few so called artifacts, some forty *Prosthennops* teeth, some of which very much resemble primate teeth, if they are not: They should be studied carefully."

Gregory (1927, p. 580) wrote the closing chapter on "*Hesperopithecus*," concluding that, "Among other material the expedition secured a series of specimens which have led the writer to doubt his former identification of the type as the upper molar of an extinct primate, and to suspect that the type specimen of *Hesperopithecus haroldcookii* may be an upper molar of a species of *Prosthennops*, an extinct genus related to the modern peccaries." Gregory (1927) made no reference to Matthew's and Cook's (1909b, p. 390) earlier tentative assignment of these teeth to *Prosthennops*, although he may have been influenced by it. The allocation is now accepted by most paleontologists and was accepted by Osborn, although he died before he could publish a statement to that effect.

Had it not been for the interest of Osborn, Matthew, Thomson, and Cook in the "*Hesperopithecus*" site on Olcott Hill, it is doubtful that Matthew's (1923a) lithologic description of the Snake Creek Formation and Cook's (1922c) selection (indirect though it was) of a type locality, would have been made. For the few years that it held the scientific interest, the enigmatic "*Hesperopithecus*" molar not only stimulated paleontological thoughts on fossil man and his

contemporaries, it directed attention to a unique set of fossiliferous deposits and virtually guaranteed their exploration.

THE 1932-1973 FRICK LABORATORY EXPEDITIONS

Frick Laboratory field parties carried on the last major phase of collecting in the Sheep Creek-Snake Creek area. In July 1932 Frick asked his one-time guide and friend of many years, John C. Blick, to contact Ashbrook, the rancher whose land included Olcott Hill and the Sinclair draws. In prior years Ashbrook had denied the American Museum field parties access to his land mostly because of his aversion to the publicity associated with their work. In an account of his meeting with Ashbrook (in lett. to Frick, July 10, 1932) Blick said: "We made it a point of calling, at the start, on Mr. Harry Ashbrook . . . who gave us permission to go over his ranch, camp, prospect, and work at any time . . . In the past the actual fossil diggers didn't leave gates open, but they did advertize themselves and their work and their visiting friends and the public did the damage. The fire hazard is *very great*." Blick also mentioned the abundance of fossil fragments on Olcott Hill and Sinclair Draw and the hazards of documenting specimens: "The utmost care in marking fossils and horizons would be necessary . . . without Dr. Matthew's Bulletin (1924) we would have been up in the air as to geology and the different horizons. It looks quite simple now after all these years of study and collecting—maybe we will know more about the Pawnee Creek before we get through with it." Frick replied on July 16, 1932, "I feel that we should avail ourselves of A's [Ashbrook's] offer immediately. The only question is as to what will be the best plan of attack on this Garden of Eden which Dr. Matthew and Thomson looked at so longingly across the fence . . . Most careful data should, of course, be kept to aid in the future solution of the question of horizons."

Late in July, 1932, Frick sent B. J. Wilson and an assistant, Carl Long, to the area. Wilson and Long had collected with Joseph Rak in the Mojave Desert and with Blick in New Mexico and

the Pawnee Creek area in Northeastern Colorado.

Wilson and Long set up their first camp on the north side of Olcott Hill and began collecting in East and West Sinclair draws, although they also sampled outcrops on Olcott Hill and Stonehouse Draw. Two months later Wilson (in lett. September 22, 1932) sent his first survey of the geology to Frick. It is reasonable to assume that Blick, from his limited knowledge of the Sheep Creek-Snake Creek beds, could not have given Wilson much of a briefing on the geologic aspects, and it was not until July 7, 1933, that Wilson (in lett.) asked Frick for Matthew's (1924a) report. Nevertheless, in two months' time Wilson conceived the sequence and superposition of interlacing channel deposits that formed the basis for the stratigraphic study of the area.

In his letter to Frick, Wilson (MS) included three maps that show channel deposits A to D in East and West Sinclair draws and Channel Z on Olcott Hill. Numbered quarries were also shown in place. A fourth illustration shows a stratigraphic section of the Sinclair draws and Olcott Hill. As examples of his channel sequence Wilson's "Horizon A" was typified by Sinclair Quarry No. 4 (=Trojan Quarry, present paper, p. 329), "Horizon B" by Sinclair Quarry No. 1 (=Snake Quarry, p. 329), "Horizon C" by Sinclair Quarry No. 2 (=East Surface Quarry, p. 333), and "Horizon D" in West Sinclair Draw (=West Sand Quarry, p. 331). Wilson's preliminary study did not entirely fit his later findings nor our interpretations (present paper, fig. 14), but he had made his first attempt to resolve the stratigraphic problems and would continue to do so during the eight years he worked in the area. Starting with specimen number one Wilson numbered his material consecutively up to 17,390, the field number for his last specimen, and furnished each number with a quarry allocation or lithologic description that denoted its place in the rock sequence.

In the summer of 1933 Wilson set up camp in Stonehouse Draw, always preferring to work close by his living headquarters. During that season and for several seasons thereafter, the greater part of Wilson's collecting was carried on in his Thompson Quarry (fig. 2), a site that he referred to as "Old Faithful" because of the seemingly

inexhaustible concentration of fossil specimens.

Late in the summer of 1934 Wilson discovered fossils in Antelope Draw (fig. 2) and from this discovery came the great collections of both the Sheep Creek and Lower Snake faunas. In Antelope Draw near the Echo-Campsite Quarry, Wilson built a two-room structure of wood and canvas that sheltered his party in the 1930s and the Skinner parties from 1941 through 1943.

Meanwhile, Frick was puzzling over the temporal allocation of a fossil cervid from Echo Quarry and wrote (June 22, 1935) to Wilson: "What can you tell us as to the horizons occurring in your present collecting pits in the quarries Echo, Campsite, Long and Hilltop of Antelope Draw? Have you ever tried to put on paper elevations showing the type of stratification at each of these? The *Dromomeryx* specimens come from the main fossil-bearing level in Echo quarry? This in your estimation represents the Lower Snake Creek of Matthew and is the same as 'Lower Snake Creek of Sinclair Draw'? But you find that the main fossil-bearing level in these Antelope Draw quarries is underlain by a possible considerably older fossil-bearing level? The Snake Creek in Sinclair Draw you once noted varied from marly to clear sand. Have you any evidence as to one type of deposition being subsequent to the other? Are both repeated in the case of Long Quarry? If it is in any way possible in collecting to distinguish between two levels in these quarries, the material should be so marked."

Wilson answered on July 21, 1935, "you will see how difficult it would be . . . to distinguish between Sheep and Snake Creek ages in Antelope Draw and so mark our material . . . the deposits are not laid down stratigraphically. Instead, the whole structure is complexed by channel fills and recuts. Younger channels recut older channel fills sometimes even below older channel floors. This is evident at Campsite, Echo, and Long quarries, and in two channels known to us in Sinclair Draw."

From 1937 to 1938 Wilson continued to revise and refine his interpretation of the "geologic phases of the Snake Creek Formation," adding to descriptions of the paleovalleys that contained the fossiliferous deposits, quarries, and modes of deposition and rocks. In November 1938 Wilson (MS) sent in his final report on the Sheep Creek-Snake Creek beds. Essentially, the geologic se-

quence of the 16 quarries that Wilson developed in the Sheep Creek-Snake Creek area is the one used in the present paper. Late in 1940 Wilson resigned from the Frick Laboratory and left fossil collecting.

Although unpublished and virtually unknown, Wilson's 1932 to 1940 field data for the study area were by far the most precise and complete of any of the collectors up to his time. Wilson was handicapped by lack of academic contacts, knowledge of previous collecting sites, and knew few, if any, of their quarry names, the main reason for the many synonyms (fig. 15). Wilson and his party discovered 16 quarries never worked by previous expeditions and was responsible for the collection of 321 boxes that contained more than 13,000 fossil specimens, each of which was given a field number and documented geographically and geologically according to prescribed Frick Laboratory methods. These data served as the starting point for the field and laboratory work of the senior author when Frick commissioned him in 1941 to collect and study in the Sheep Creek-Snake Creek area.

Skinner and his party entered the area on May 12, 1941, and began intensive quarry work that lasted through 1947. From then to the present Skinner made yearly visits and study trips reviewing geology and revising notes and stratigraphic sections that are the basic data for the present report. Skinner is responsible for the collection and field data for the Frick Laboratory Sioux County boxes 322 to 620, the last two boxes having been collected in July, 1972, and the last specimens in June, 1975.

DISCUSSION

Throughout the published (and unpublished) history of the Sheep Creek-Snake Creek beds one encounters the charge that the field data are unreliable and that the faunas had been mixed. After 1916, however, the field data, catalogues, faunas, and publications show that some of the commixture started with authors rather than field data. Eagerness to report faunas that filled a gap in the fossil record of the early 1900s and too little field study led some writers to make biostratigraphic diagnoses that disregarded the fossil-producing rocks.

Matthew and Cook (1909b) and Matthew

(1918, 1924a) failed to differentiate between rocks containing the Lower Snake Creek Fauna (Early Barstovian) in the Sinclair draws, and the Snake Creek rocks that contained the Early Clarendonian fauna of the Murphy Member on Olcott Hill and in East *Pliohippus* Draw, the Late Clarendonian fauna of the Laucomer Member on Olcott Hill, the *Aphelops* Draw Fauna (Early Hemphillian) in *Aphelops* Draw and the ZX Bar Local Fauna (Late Hemphillian) in East *Pliohippus* Draw. Although Matthew (1924a) clearly distinguished between the Lower Snake Creek and Snake Creek faunas, he believed that the deposits in Sinclair Draw and those on Olcott Hill were one set of rocks—the Snake Creek Formation. From 1908 through 1927 American Museum parties led by Thomson, and the 1914 Princeton party led by Sinclair, followed Matthew's concept in documenting their collections.

Matthew (1918, 1924a) and Sinclair (1915) in their reports (Osborn, 1918, 1936, used Matthew's data), and Thomson and Whitford in their letters and field lists, at no time confused the Sheep Creek rocks and faunas with those of the Olcott Formation and Lower Snake Creek Fauna. This interpretation was made by Lugn (1939) and was followed by various authors (Elias, 1942; Schultz and Falkenbach, 1947, 1949, 1968; Schultz and Stout, 1941, 1961).

A. L. Lugn was a dedicated geologist whose brief reconnaissances of the Sheep Creek-Snake Creek beds left too little time for him to untangle their complex depositional history. As a result, he expanded the Hemingfordian Sheep Creek Formation to include the local rocks that yielded the Barstovian Lower Snake Creek Fauna, and extended the Sheep Creek Formation out of its type area to include rocks of very different lithology. Thus, the rocks that contained the Lower Snake Creek Fauna came to have two identities, neither of which was correct. In 1939 (p. 1255) A. L. Lugn stated: "Unfortunately, 'Snake Creek' has been incorrectly (?) applied to beds, mainly channel fills, as late as Pleistocene and to other beds as old as Miocene. Much of the Miocene 'Snake Creek' or perhaps the so-called 'lower Snake Creek' seems to be in part not Snake Creek at all but Sheep Creek channel beds in place and in proper stratigraphic sequence."

A. L. Lugn could not have seen the marked erosional unconformity between the Sheep Creek

Formation and the Olcott Formation (present paper, fig. 4 A-C). Lugn also charged that poor field records and faunal mixing by collectors had caused the misinterpretation of the Sheep Creek-Snake Creek beds. A. L. Lugn's concept, which had little faunal basis, has been rejected by many paleontologists.

McKenna (1965) cleared away much of the confusion when he presented a detailed analysis of the literature relating to the Miocene stratigraphy and vertebrate paleontology of western Nebraska. Although his analysis concerned mainly studies of the Hemingford Group (i.e., Marsland and Sheep Creek formations), McKenna (1965, fig. 1) gave his interpretation of the "lithostratigraphic nomenclature, equivalence, and sequence" of formations in the Arikaree, Hemingford, and Ogallala groups. This study brought together for the first time the whole spectrum of original and later usages for rock and time terms of the Sheep Creek-Snake Creek beds and has been of utmost usefulness. In the present paper the Marsland Formation equals the Upper Harrison of Peterson, 1907. We are also in agreement with Galusha (1975) in his redefinition and delineation of the Box Butte Formation when he showed that contrary to previous authors the Box Butte is stratigraphically earlier and lithologically distinct from the Sheep Creek Formation.

The letters of Osborn and Matthew to Thomson in the American Museum Department of Vertebrate Paleontology archives clearly requested detailed field data and geology, but omitted requests for geographic locations of faunal sites such as those given by Sinclair (1915). Local names applied to various draws seemed sufficient. Nevertheless, Whitford (MS.b) supplied geologic sections, stratigraphic notes, and geographic descriptions, most of which were apparently ignored. Wilson furnished detailed sketch maps with quarries and channel deposits indicated, but gave no geographic descriptions. Later, Skinner, with the help of Wilson's assistant, Ronald Martin, was able to relocate the Frick sites.

With the exception of Thomson, Whitford, and Wilson, Cook was probably the person most familiar with the area and could have given detailed geographic descriptions for the many fossil sites from which he collected. Yet no such de-

TABLE 2
Unpublished Records of Collectors

Year and Collector	Institution	Descriptions			Stratigraphic Section	Specimen Lists	Photographs, Letters, Diaries
		Geographic Map	Lithic				
1908-1922, Matthew ^a	AMNH	None	None	None	None	None	Letters ^b to Osborn, Thomson
1908-1927, Thomson	AMNH	Map	Generalized	Generalized	Generalized	Field Lists	Photographs, ^b letters ^b to Matthew, Osborn, Granger
1908-1962, Cook ^c	AMNH	None	Generalized	Generalized	Generalized	Catalogue	Catalogue best source; diaries not seen
1914, Sinclair, Whitford	PU	Detailed and map	Generalized	Generalized	Generalized	Field Lists	Photographs, ^d diaries ^d
1916, Whitford	AMNH	Detailed	Detailed	Detailed	Detailed	Misplaced or lost	AMNH Annual Report for 1916
1923-1925, Sorensen	AMNH	—	—	—	—	—	Photographs, ^b diary, ^b furnish data on weather, collecting, personnel
1932-1940, Wilson	AMNH	Detailed and map	Detailed	Detailed	Detailed	Detailed for each specimen	Photographs, ^e informal reports, ^e letters ^e to Frick

^a Although Matthew did not make yearly visits to the area, he spent a month to six weeks at each visit.

^b The American Museum of Natural History archives, Department of Vertebrate Paleontology.

^c Cook's widow gave most of his private collection and catalogue to the American Museum of Natural History in 1963. Cook's diaries are said to be in the National Park Service archives.

^d Princeton archives, Princeton University.

^e Frick archives, the American Museum of Natural History.

TABLE 3
Summary of Published Sheep Creek-Snake Creek Data

Year and Author(s)	Geographic ^a Location of Faunal Sites	Geologic Lithic Descriptions, Stratigraphic Sections, ^b Rock Units Mentioned	Authors' Usages Biostratigraphic Correlations, Temporal Allocations
1908. Matthew and Cook, p. 196	Divide between Niobrara and Platte rivers, Sioux Co., Nebr.	Generalized lithology: Ogallala; Pawnee Cr. beds	Early Pliocene overlying Medial Miocene; preliminary discussion of taxa
1909b. Matthew and Cook, p. 362, etc.	As above, and headwaters of Snake, Sheep, and Spotted Tail creeks	Generalized lithology; Snake Creek beds defined, referred to Ogallala Sheep Creek beds defined, compared with Pawnee Creek, Deep River, Mescal	Snake Creek fauna described as Early Pliocene Medial Miocene. Faunas undescribed
1910. Matthew, p. 353	As above	Labeled photograph shows "Snake Creek beds" (=Olcott Fm.) overlying Sheep Creek Fm. Sheep Creek beds	Early Pliocene " <i>Neotragocerus</i> zone." Snake Creek faunal list Miocene. Faunas not listed.
1912. Cook, p. 43	Sioux Country, Nebr.	Snake Creek beds Sheep Creek beds	Early Pliocene, <i>Neotragocerus</i> zone. Snake Creek faunal list Medial Miocene, First Sheep Creek faunal list
1914. Cook, p. 49	None given	Snake Creek beds	Early Pliocene. <i>Amphicyon amnicola</i> described
1915. Sinclair, p. 73	Real estate descriptions for faunal sites	Generalized lithology Snake Creek beds	Early Pliocene. Faunal list, new taxa described
1915. Matthew, p. 377	None given	Snake Creek and Sheep Creek beds	Faunal correlation charts for North America and Europe
1918. Matthew, pp. 183-229	None given	Generalized lithology Snake Creek beds Sheep Creek beds	Early Pliocene. Revised faunal list, doubts all of the same age No faunas
1918. Osborn, p. 34 (<i>fide</i> Matthew) Ms. a	General location	Generalized lithology, stratigraphic section (Osborn, 1918, p. 102, from Thomson MS.a) Snake Creek (Upper, pp. 34, 145) Snake Creek (Lower, p. 34) Sheep Creek Formation, phase of Arikaree Formation, pp. 99, 102	<i>Pliauchenia-Peraceras</i> Zone, Early Pliocene <i>Procamelus-Hipparion</i> Zone, transitional Mio-Pliocene <i>Ticholeptus-Merychippus</i> Zone, Early Medial Miocene
1921. Osborn	Western Nebraska, Sioux County	Snake Creek B	Early Pliocene, <i>Procamelus-Hipparion</i> Zone correlated with North American Fort Niobrara, Clarendon, Santa Fe Marls B, and with European Pikermi-Eppelsheim faunas
1922b. Cook	Southern Sioux County, Nebr.	Snake Creek beds	Faunas compared with those from Wray, Colorado
1922. Osborn (<i>fide</i> Cook)	General location	Upper part Snake Creek beds typical locality	Upper or <i>Hipparion affine</i> zone of Snake Creek beds

TABLE 3 – (Continued)

Year and Author(s)	Geographic ^a Location of Faunal Sites	Geologic Lithic Descriptions, Stratigraphic Sections, ^b Rock Units Mentioned	Authors' Usages Biostratigraphic Correlations, Temporal Allocations
1923a. Matthew	Olcott Hill, 20 mi. S of Agate, type locality for Upper Snake Creek beds	Detailed lithology Upper Snake Creek channel beds Lower Snake Creek beds Sheep Creek beds	Early Pliocene; first faunal list Late Miocene Not mentioned
1923b. Matthew	Snake Creek fossil quarries 20 mi. S of Agate, Sioux Co., Nebr.	Snake Creek Sheep Creek	Early Pliocene: ?4) <i>Pliohip- pus leidymanus</i> zone Early Pliocene: 3) <i>Hipparion affine</i> zone Late Medial or Late Miocene: 2) <i>Merychippus paniensis</i> zone Early Medial Miocene: 1) <i>Merychippus primus</i> zone
1924a. Matthew, pp. 64-68	Main draws named	Snake Creek Formation included: Upper Snake Creek Lower Snake Creek Sheep Creek Lower Sheep Creek	" <i>Pliohippus leidymanus</i> zone and <i>Hipparion affine</i> zone" " <i>Merychippus paniensis</i> zone" " <i>Merychippus primus</i> zone" "Horiz. A, Stonehouse Draw"
1924b. Matthew, pp. 750-751, charts	Not given	Upper Snake Creek Lower Snake Creek Sheep Creek	Republican River of Kansas Pawnee Creek and Deep River Phillips Ranch
1936. Osborn, pp. 426, 427	Detailed locations for seven AMNH Qs., <i>fide</i> Thomson's (MS.g) map	Generalized stratigraphic sec- tions of "Sheep Creek and Snake Creek" Qs. showing Arikaree, Sheep Cr., Lower Snake Cr. =Horizon A, Upper Snake Cr. =Horizon B	Lower Pliocene Snake Cr. B: Qs. 1, 3, 4, 5, 7 Upper Miocene Snake Cr. A: Qs. 2, 6
1939. Lugn, pp. 1254-1258	Type locality for Sheep Creek and Snake Creek formations in "south-central Sioux County, Nebraska."	Base map shows Hemingford Group (=Sheep Creek and Marsland formations) as one rock unit. Snake Creek Fm. not shown—described as "channel fill material." Slump blocks (=Snake Creek Fm.) identified as Sheep Creek Fm., "Lower Snake Creek beds" referred to Sheep Creek Fm., and Sheep Creek expanded beyond lithic continuity	Medial to Late Miocene Sheep Creek Fm. "can be zoned ... into at least three floral or fossil seed zones." Postulated that "Miocene 'Snake Creek' " (=Olcott Fm.) beds are Sheep Creek channels in place, but gave no substantiating data
1942. Elias, pp. 126-131	"15 Mi. S., 1 Mi. E. of Agate, ... West Kil- patrick, <i>Aphelops</i> , and <i>Pliohippus</i> draws at the head of [Dry] Spottedtail Creek." Osborn (1918, p. 17) cited for type section. (See fig. 13, present paper.)	Sheep Creek expanded to in- clude three members: Spotted Tail = Sheep Creek <i>sensu</i> Matthew, 1924a, except up- per 10-20 feet of sediments with dark gray ash Sand Canyon =sediments 50 mi. E with "similar" dark gray ash and identical fossil fruit (<i>S. dawesense</i>)	Medial to Late Hemingford Group extending to Early Pliocene Ogallala 1. <i>Stipidium minimum</i> zone 2. <i>Stipidium dawesense</i> zone

TABLE 3 – (Continued)

Year and Author(s)	Geographic ^a Location of Faunal Sites	Geologic		Authors' Usages Biostratigraphic Correlations, Temporal Allocations
		Lithic Descriptions, Stratigraphic Sections, ^b	Rock Units Mentioned	
		Box Butte =deposits overlying highest zone of Marsland; no contact between Box Butte and Sand Canyon; fossil flora de- termined inclusion of Box Butte in Sheep Creek Fm.		3. <i>S. dawesense</i> and <i>S.</i> <i>commune</i> zone
1965. McKenna, pp. 2-17, fig. 1.	Type locality Sheep Creek described <i>fide</i> Elias (1942) Type locality Upper Harrison of Peterson (1907) described	Diagram of rock unit names, equiv- alence, and sequence, including Arikaree, Hemingford, and Ogallala groups Marsland Formation =Upper Harri- son beds of Peterson (1907). Summary of authors' (1902- 1965) concepts of rock units in relation to Sheep Creek- Snake Creek beds		Upper Snake Creek = <i>Plio- hippus leidyani</i> zone? and <i>Hipparion affine</i> zone of Matthew (1924a) and Upper Ogallala of Lugn (1938) Lower Snake Creek = <i>Merychippus paniensis</i> zone of Matthew (1924a) Sheep Creek = <i>Merychippus</i> <i>primus</i> zone of Matthew (1924a).
1975. Galusha, fig. 2, pp. 50-52	Type locality Sand Canyon Member, Sheep Creek Fm. described <i>fide</i> Elias (1942)	Correlation charts showing authors' (1933-1975) con- cepts of rock units in relation to stratigraphic position of Box Butte Formation and the Sheep Creek-Snake Creek beds		Box Butte Formation older than Sheep Creek Forma- tion. Sand Canyon Member equiv- alent in time to Lower Snake Creek beds

^aThe only map available was the Nebraska Whistle Creek Quadrangle of 1899 that had some serious errors in elevations (present paper, p. 276). Its small scale (½ inch to the mile) made it difficult for the earlier workers to give accurate real estate descriptions.

^bThe published stratigraphic sections in the Sheep Creek-Snake Creek area were diagrammatic and idealized. No relative elevations, and few, if any, thicknesses were given.

scriptions appear in Cook's publications or catalogue. He supplied his own local geographic names that can be interpreted only by one familiar with the area and his style of documentation. Cook's mileages from Agate to the area varied from 1 to 5 miles for the same sites, and he sometimes gave wrong directions (e.g., east instead of west). Cryptic and sometimes unreliable though it is, Cook's catalogue supplied essential data for the stratigraphic details of his collection.

Years later when ill health precluded any possibility of arduous field work, Cook (1951, p. 89) expressed his regret over the early documentation of the Sheep Creek-Snake Creek faunas and localities: "an unusually full record [faunal]

exists but unfortunately it is so complicated and involved, and the early collecting and recording were so inexact, that the picture is confused, rather than clarified. I am one of those guilty of this condition being true, as I made, with W. D. Matthew, the original discovery of these beds, and reported them with him. I can freely say that we did not at first, or for a long subsequent period, know of this complexity or comprehend many of the facts and factors we now know, and did not realize the critical necessity here for exact mapping, unusually careful observation of depositional data in these highly complicated and interlaced deposits, as well as precise recording of the occurrence of all fossils. This can still be

done by collectors with the proper training and understanding of the problem in hand, and sufficiently equipped with the means to carry it out."

In the present paper table 2 gives a chronological review of available data in the collectors' unpublished records. After 1918 Thomson distinctly separated specimens by quarry allocation, thereby making it possible for various taxa to be given their proper provenance in time and space. Thomson's field data have been largely overlooked, and, as is the case with many early day professional collectors, he did not publish his observations, although Osborn (1936, fig. 392) published Thomson's field map (present report, fig. 16) on which most of the American Museum quarries (1908-1926) were located.

Table 3 summarizes only those published re-

ports that were significant in terms of their influence on later studies. These reports dealt mainly with faunas, the most important by far being those of Matthew and Cook (1909b), Matthew (1918, 1924a, 1932). Those of A. L. Lugen (1939) and Elias (1942) dealt mainly with rocks, although Elias also used fossil grass seeds in his correlation. The Wood Committee (1941) is not included in this summary, because their report was based on literature that completely ignored Matthew's and Osborn's contributions. The Wood Committee credited vague and unreliable field records as the reason for conflicting data on the Snake Creek, whereas the real reasons were unfamiliarity with geography, misinterpretations of the rocks, and disregard of field records after 1916.

TERTIARY SYSTEM. STRATIGRAPHY OF THE SEDIMENTARY ROCKS

Figures 1, 3-7

The stratigraphic sections A through F (figs. 4-7) diagrammatically illustrate the relations of the quarries that were developed in the Sheep Creek-Snake Creek area from 1908 to 1945. These diagrams also suggest paleovalley walls and paleoland surfaces that single sections cannot show. Each diagram represents several local stratigraphic sections that were made in combination with elevational controls and in the same detail as that illustrated for the type sediments of the Sheep Creek Formation on section E (fig. 6). Data for these stratigraphic sections are derived from studies of outcrops in the area, fresh quarry excavations, the major aspects of the lithology of the Harrison, Marsland (=Upper Harrison, Peterson, 1907), Sheep Creek, Olcott (New) formations, and the restricted and revised Snake Creek Formation, as well as a secondary knowledge of taxa derived from the fossil sites.

ARIKAREE GROUP

HARRISON FORMATION

Figures 1B, 3-6, 8-13

Name and Definition. Of the Miocene Ari-

karee Group only the Harrison is exposed in the study area. Hatcher (1902, p. 117) proposed the name "Harrison beds," stating that the deposits "are well shown in the bluffs of all the small streams that head near the summit of Pine Ridge, in the vicinity of Harrison, Nebraska. They are also known to cover a considerable area to the east, west and south of that village, extending well into the State of Wyoming. They are composed of about 200 feet of fine-grained, rather incoherent sandstones, permeated by great numbers of siliceous tubes arranged vertically rather than horizontally. They are further characterized by the presence, often in the greatest abundance, of these peculiar and interesting, but as yet not well understood, fossils known as *Daemonelix*, and by a considerable variety of fossil mammals belonging to characteristic Miocene genera. They immediately and conformably overlie the Monroe Creek beds and pass insensibly into them."

Other than the geographic description that Hatcher gave, a formally described type section has not been published. On a greatly reduced township map, and without geographic description, Peckham (1961) indicated, by circling his locality no. 4, that he considered it to be the type section.

Lithology. The major part of the Harrison

Formation is windblown, and consists mostly of consolidated massive beds of silt and fine "pepper and salt" sand with an overall gray appearance. The *Daemonelix*, the cemented, agatized layer that locally caps the formation (informally known as the Agate Lime), and the siliceous tubules are all secondary features. The Agate Lime may be equal to a local caliche zone or weathering surface between the Harrison and the Marsland (=Upper Harrison of Peterson, 1907) formations.

Volcanism in Harrison time (Late Arikareean) resulted in at least one and probably two ash layers. A white, friable, compact ash (informally called the Agate Ash) was dated at 21.3 m.y. by Evernden et al. (1964, table 6). It is a local volcanic debris that thins and thickens rapidly. The type outcrop where Cook collected his sample (KA 481) is an easily accessible deposit from 7 to 8 feet thick on the north side of the Niobrara River, about 2 miles east of the former Agate post office, Sioux County, Nebraska, in the SE $\frac{1}{4}$, SW $\frac{1}{4}$, sect. 4, T. 28 N, R. 55 W, now in the Agate Fossil Beds National Monument. The base of the ash occurs at its type locality at an elevation of 4465 feet in the Harrison Formation, some 45 feet above the Niobrara River level, about 30 feet below the Agate Springs quarries, and about 85 feet below the local contact (as defined by the Agate Lime) between the Harrison and Marsland formations. Another ashfall (bluish gray) is present on the west side of the Spoon Buttes in Wyoming, but has not been dated nor correlated with the Agate ash.

Distribution and Thickness. The Harrison Formation underlies the Niobrara River Valley in western Sioux County in almost continuous outcrop, is well exposed at the surface as far north as the Pine Ridge escarpments; isolated outcrops can be recognized to the northeast at the east end of Slim Butte in the SW $\frac{1}{4}$, sect. 16, T. 36 N, R. 47 W, Shannon County, South Dakota, where more than 100 feet of Harrison sediments are exposed in unconformable contact on the underlying Monroe Creek Formation. The Harrison Formation extends into eastern Wyoming (Spoon Buttes, eastern Goshute County), and farther west where it laps against the Hartville Uplift. Southward, it is exposed along the

escarpment in the Platte River valley as far as western Morrill County, Nebraska.

In the limited study area the Harrison Formation forms the basement rock for the overlying Sheep Creek, Olcott, and Snake Creek formations (see map, fig. 3).

An eastward extension of the Harrison Formation, hitherto unreported, occurs in the Niobrara River Valley at its junction with Bear Creek in Cherry County, Nebraska. The sediments are the typical gray sand of the Harrison. Some 25 miles farther east two other small outcrops in road cuts on the north side of the Niobrara River are exposed wherein the Harrison is overlain by the Crookston Bridge Member of the Valentine Formation. These Harrison outcrops are in the NW $\frac{1}{4}$, sect. 33, T. 33 N, R. 31 W, and $\frac{1}{8}$ mile below the mouth of McCann's Canyon on the south side of the NW $\frac{1}{4}$, NE $\frac{1}{4}$, sect. 32, T. 33 N, R. 31 W, Cherry County, Nebraska, a short distance above the mouth of the Snake River. A colubrid snake skeleton and a rodent jaw (*Paleocastor fossor* Peterson, 1906, *fide* T. M. Stout, personal commun.) were collected from these outcrops.

The thickness of the Harrison Formation is usually considered to be between 200 and 300 feet. Some of the elevational checks, however, suggest that there could be several hundred more feet in local spots (e.g., base of the Harrison Formation at Andrews, Nebraska, fig. 1A, at about 4500 feet on the Niobrara River and the top of the Pine Ridge escarpment northwest of Harrison, Nebraska, at about 5200 feet).

Stratigraphic Relations. The contact between the gray silt and sand of the Harrison and the tan to pink, buff, fine silt and sand of the Marsland (=Upper Harrison) in the study area is sharp. Locally, no basal conglomerate has been observed at the base of the Marsland Formation.

On the west side of the study area typical Harrison sediments crop out along abandoned Nebraska Highway 29 just east of the base of Tower Hill (fig. 6E, right side) near USC & GS bench mark P-58 (table 1). Typical massive gray sand with concretionary layers are exposed, but no *Daemonelix* has been observed locally. The contact between the Harrison and the overlying Marsland is sod covered, but within a 7 to 10 foot interval a pronounced lithic change occurs

from Harrison to Marsland type sediments. The highest exposed Harrison sediments are at an elevation of 4862 feet, well above the type Sheep Creek silts that are exposed on the head of Dry Spotted Tail Creek and part of which some authors have referred to the Marsland Formation. The Harrison crops out just above the hand dug Ashbrook well south of the junction of *Aphelops* and *Merychippus* draws, southward down the drainage to the vicinity of the Snake Den Hills, *Pliohippus* Draw, and below Ashbrook Quarry (fig. 2). Near the junction of *Pliohippus* Draw with Dry Spotted Tail Creek (figs. 2 and 6E) and the North and South Snake Den Hills, a coarse basal conglomerate in the Sheep Creek Formation overlies the Harrison with about 70 feet of relief. The conglomerate, which ranges in thickness from 0 to 25 feet, was deposited on the irregular paleosurface of the Harrison-Sheep Creek contact. *Merychippus primus* was collected from this conglomerate (p. 295).

On the east side of the study area, stratigraphic section A (fig. 4A) shows the Harrison land surface prior to Sheep Creek deposition. In Antelope Draw, in the south fork of Ranch House Draw, and to the north of Olcott Hill (fig. 2 overlay), the Harrison crops out with zones of concretionary sandstone. In Antelope Draw the surface of the Harrison is unweathered and is immediately overlain by the Sheep Creek with no intervening basal conglomerate, in contrast to the contact between the Harrison and Olcott formations in the Sinclair Draw area, and at Boulder Quarry on the northeast face of Olcott Hill, where a 5 to 6 foot weathered zone in the Harrison lies just below the Olcott Formation (fig. 5D), indicating a period of nondeposition.

The Harrison Formation is also unweathered at its contact with the Olcott Formation in Antelope Draw below the Echo Quarry channel deposit (fig. 4A, right side) and in Ranch House Draw below Humbug Quarry (fig. 4A). Thus two types of Harrison-Olcott contacts are present in the area, one weathered and one unweathered. At Echo Quarry a local zone of cementation about one foot thick, with reworked Sheep Creek matrix and fossil fragments, is present directly below the deeply incised part of an Olcott paleovalley that has been filled with Echo Quarry

deposits. At Humbug Quarry the Olcott Formation also rests on the unweathered Harrison Formation.

At the northwest end of Olcott Hill a Harrison "high" (elevation about 4889 feet) strongly suggests the south wall of the Sheep Creek paleovalley (fig. 4A, left side). One isolated outcrop of Sheep Creek north of Olcott Hill and southeast of the main Antelope Draw quarries shows about 15 feet of exposed Harrison sediments overlain by about 18 feet of consolidated conglomerate in the lower part of the Sheep Creek. The elevation of the contact is 4795 feet and shows that 94 feet of local relief developed on the surface of the Harrison Formation before deposition of the Sheep Creek (fig. 4A).

Harrison sediments are in erosional contact with the overlying Sheep Creek Formation at Coyote Draw on the north and reappear at the junction of Stonehouse and East Stonehouse draws on the south (fig. 4B).

HEMINGFORD GROUP

MARSLAND FORMATION

Figures 1B, 6E, 8, 9

Inclusion of the Marsland Formation in the stratigraphic section of the present paper serves two purposes: (1) To present a brief history of the tangled nomenclature and the type locality of the Marsland (=Upper Harrison). (2) To illustrate the absence (rather than the presence, as suggested by Schultz and Falkenbach, 1947) of the Marsland Formation beneath the Sheep Creek and later rocks in the study area. For a more comprehensive treatment of the Marsland Formation, McKenna (1965) is recommended.

Name and Type Locality. Hatcher (1902, p. 117) first recognized the post-Harrison beds in western Nebraska and adjacent Wyoming as: "The Nebraska Beds, of Scott . . . a series of buff-colored sandstones of varying degrees of hardness and unknown thickness, with occasional layers of siliceous (not calcareous) grits, which protrude as hard, indurated or shelving masses from the underlying and overlying softer materials . . . They are represented at various localities along the Niobrara River, south of Harrison, Nebraska, where they are of unknown thickness and imme-

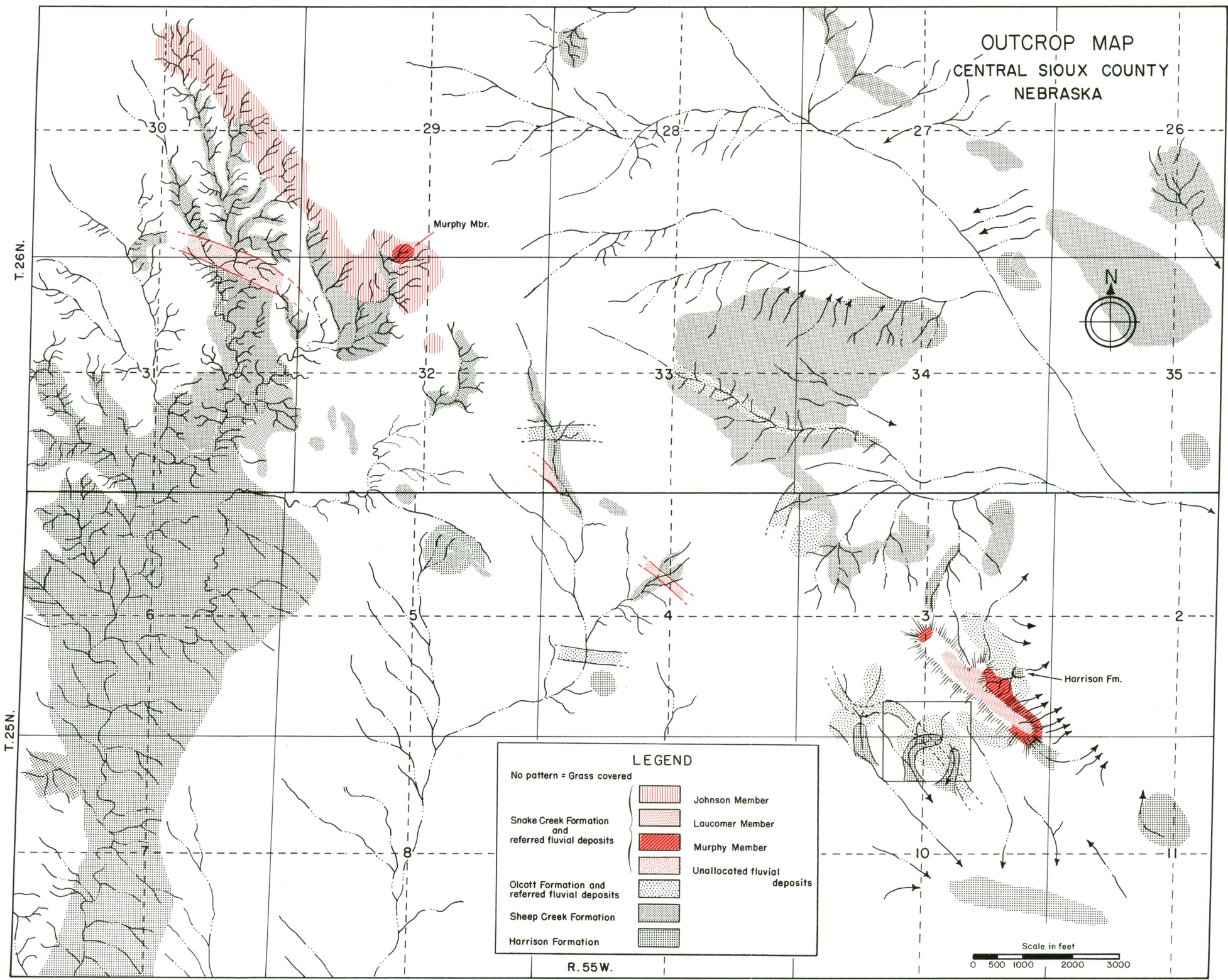


FIG. 3. Part of central Sioux County, western Nebraska, showing outcrops of Sheep Creek, Olcott, and Snake Creek formations.

diately overlie the Harrison beds. Toward the south they pass beneath the Ogallala formation."

Peterson (1904, pp. 473, 474, fig. 3), following Hatcher, included the "Nebraska Beds" in his Loup Fork series in Sioux County, Nebraska, estimated the vertical thickness as "no greater than 150 to 200 feet," and illustrated the deposits in an "Ideal section of Miocene formations from Squaw Butte to the south side of Running Water River [Niobrara]."

Three years later Peterson (1907, p. 22, fig. 3a) changed his "Nebraska Beds" assignment of the buff-colored sandstones: "From a verbal statement . . . by H. F. Osborn it now appears that . . . the Nebraska beds are of later origin than those, which, in former papers, I have referred to that horizon. This horizon, therefore, may be called the Upper Harrison beds and in this paper will be referred to under that name." Peterson (1907, p. 23, fig. 1) illustrated a section from Squaw Butte on the north to Spoon Butte on the south, showing the superposition of the Upper Harrison to the Lower Harrison, and remarked that the sandstone that capped Spoon Butte "is regarded as the top of the Upper Harrison beds."

Osborn (1909, p. 74), on faunal evidence, placed Peterson's Upper Harrison in an "Upper Division" thus separating it from the Harrison, Monroe Creek, and Gering formations, which were in his "Lower Division." Osborn (1909, fig. 14) also presented a section from Squaw Butte to Spoon Butte, eastern Wyoming and western Nebraska, but showed no lithic break between the Upper and Lower Harrison formations. Osborn (1909, pl. 2), however, illustrated the exact location of his stratigraphic section on his map.

On the authority of Matthew's and Cook's (1909a, p. 196) citation of a "marginal phase of the Ogallala formation . . . mantling the Miocene beds" in Sioux County, Nebraska, Peterson (1909, pp. 74-75, fig. 27) removed the pink sandstone that capped the Spoon Butte from his concept of the Upper Harrison and named the sandstone the Spoon Butte Beds. At the same time Peterson (1909, p. 75) explicitly set the type locality of his Upper Harrison: "Places of non-conformity between the upper and lower Harri-

son beds are frequently found, the first of which . . . is situated immediately east of the Niobrara-Wyoming State line. This is in reality the type locality of the upper Harrison beds."

Schultz (1938, p. 443) proposed a replacement name, Marsland, for Peterson's (1907) Upper Harrison, giving the locality thus: "To the deposits ('upper Harrison beds') which immediately overlie the Arikaree group and which are faunally and lithologically distinct from the typical Arikaree, the writer suggests the name Marsland formation. This formation is best exposed in Nebraska in the region about Marsland along the Niobrara River where it includes some 150 feet of buff and gray, soft sandstones. The Marsland consists, in part, of valley fills, and in places seems to mantle the slopes of certain large valleys. The upper part of the Marsland formation in this region is more gritty and is mostly buff-colored." Schultz's description purports to be a comparison of the local sediments around Marsland with the Upper Harrison of Peterson (1907).

Schultz (1941, pp. 1990, 1991) apparently overlooked Peterson's (1909, p. 75) selection of a type locality for his Upper Harrison when Schultz stated: "The Marsland formation of the Hemingford group of the Miocene has now been traced from the type area southwest of Marsland, Nebraska, in sections 23 to 27, T. 28 N., R. 52 W., and sections 19 and 30, T. 28 N., R. 51 W. to the adjoining States of Colorado, South Dakota, and Wyoming . . . In Nebraska and Wyoming, the Marsland includes all the deposits formerly called 'Upper Harrison.'"

According to the Code of Stratigraphic Nomenclature (Art. 13 [h], pp. 653, 654), "Type sections cannot be changed. There may be more than one typical section but only one type section." The rocks that Schultz (1941) cited for the "type area" of his Marsland are not the same as Peterson's (1909) type Upper Harrison exposed on the Niobrara River just east of the Nebraska-Wyoming state line. Note that Peterson (1907, 1909) did not mention the area that Schultz (1941) cited for the type Marsland. Peterson's (1909) type locality cannot be changed, nor can the type locality be expanded southeastward for some 30 miles. Peterson's

Upper Harrison rocks are still the sediments that Schultz (1938) renamed Marsland.

If Schultz (1938, 1941) had never mentioned Peterson's Upper Harrison, and had only applied the name "Marsland" to a type section and sediments in the area around Marsland village, there would have been no need for Cook (1965) to have described the Runningwater Formation. In the present paper we use the name Marsland as a replacement name for Peterson's (1907) Upper Harrison (following McKenna, 1965). Part of the deposits that Schultz (1938) called "The upper part of the Marsland" is now referable to the younger Runningwater Formation.

In a revision of the classification of the Tertiary lithologic units in western Nebraska, A. L. Lugin (1939, pp. 1253-1254) placed the Marsland Formation as the lowermost formation of the Hemingford Group. A. L. Lugin (1939, p. 1254) stated his reason for the assignment: "these buff to reddish-brown beds have never had a proper name until the term Marsland was proposed recently (Schultz, 1938). The application of the name 'upper Harrison' to these beds by Peterson (1906) and others (Cook, 1915) in more recent years has been unfortunate because these beds (Marsland) have no very close stratigraphic or faunal relation to the true Harrison (in the Hatcher sense) and are separated from the underlying Harrison formation by the most significant and important structural and erosional unconformity within the Miocene series in western Nebraska. The time of the major folding which produced the Agate anticline and certain other structures in western Nebraska seems to have been post-Harrison pre-Marsland."

Marsland Outcrops in the Study Area. The only outcrops of Marsland (=Upper Harrison) sediments in the study area are on the north and west sides of Tower Hill, which is situated 3½ miles northwest of *Aphelops* Draw (figs. 1, 6E). Tower Hill is a remnant of the north wall of a paleovalley that once contained Sheep Creek and Snake Creek deposits. Here the Marsland rests directly on the Harrison (typical gray sand with concretionary layers); no *Daemonelices* were observed, nor have fossils been taken from either the Harrison or the Marsland formations at Tower Hill, so far as it is known. Lithologically, the Marsland on Tower Hill is the same massive

sand and silt as Marsland sediments north and south of Agate, and in other areas that Peterson (1907, 1909) defined as the Upper Harrison. The elevation of the top of the Marsland on Tower Hill is about 4985 feet, higher than any known Sheep Creek, and as high as Snake Creek deposits to the south. Overlying the sod-covered Marsland (fig. 6E), a bed of reddish, clay-filled sand, with local white nodular spots, crops out vertically for some 30 feet; the correlation of this deposit is uncertain.

The south wall of the paleovalley, with only a small part preserved, is situated about 4 miles to the south-southeast of Tower Hill near Ashbrook Quarry (fig. 6E). The south wall would have been about as high (4985 feet) as the north wall at Tower Hill. Below Ashbrook Quarry (fig. 6E), the relief shows that the south side of the paleovalley was formed of Harrison sediments, against which the Sheep Creek was deposited. The initial Sheep Creek deposit is a basal conglomerate at least 10 feet thick, composed of reworked, well-rounded pebbles of Harrison concretions, quite unlike the Marsland Formation in which no basal conglomerate has been observed. The Marsland appears to have been a mantling formation, in part at least.

In reference to the provenance of a *Merychippus* cf. *elegans* skull (AMNH 20523), Schultz and Falkenbach (1947, p. 203) suggested that, in *Aphelops* Draw, "some of the pinkish sands below the quarries might well represent upper Marsland deposits." These pinkish sands, which are not Marsland sediments, but are in the lower part of the Sheep Creek Formation, also occur north of Ashbrook Quarry near Snake Den Hills (fig. 6E), above a basal conglomerate from which *Merychippus primus* teeth (upper and lower) were collected by the senior author. These *M. primus* teeth are well covered with cement and more advanced than any equid dentition from Marsland (=Upper Harrison) and Runningwater formations.

The pinkish sands in the lower part of the Sheep Creek Formation also crop out on the south fork of a tributary of Antelope Draw, south of Echo Quarry, north of Thomson Quarry in Stonehouse Draw, and above the fossil-producing matrix of Greenside Quarry in Ranch House Draw. The occurrence of *Merychippus*

primus in the basal conglomerate of the Sheep Creek Formation north of Ashbrook Quarry at an elevation of 4753 feet, is compatible with the occurrence of *M. primus* from Greenside and Long quarries at elevations of 4794 and 4814 feet, when the widely varying elevations of the Harrison Formations are considered (figs. 1B, 4 A-C).

Following Schultz and Falkenbach (1947), Folsom (MS) and R. V. Lugn (MS) also interpreted the lower part of the Sheep Creek in *Plihippus* Draw as Marsland sediments. Folsom (MS), in his map and stratigraphic section, identified 60 feet of Sheep Creek as Marsland, and R. V. Lugn (MS) cited 50 to 65 feet of Sheep Creek as Marsland in his stratigraphic section.

The "Upper" Marsland (=Runningwater Formation) of Schultz and Falkenbach (1947) and Schultz and Stout (1961) bears no lithic resemblance to the lower part of the Sheep Creek Formation except that of a pinkish color, nor is there a faunal similarity. If any part of the Sheep Creek Formation contains an Early Hemingfordian fauna that is equivalent to the "Upper" Marsland (=Runningwater Formation), as suggested by Schultz and Falkenbach (1947, p. 203), Folsom (MS), and R. V. Lugn (MS), the faunas from Greenside and Long quarries should bear the closest affinities and they do not. Fossils from these quarries, and, in fact, fossils from all known Sheep Creek quarries, indicate a long hiatus between the Marsland Formation (=Upper Harrison) and the Sheep Creek Formation.

SHEEP CREEK FORMATION

Figures 1-4, 6, 7, 10

Name and Definition. The Sheep Creek Formation was originally described and named by Matthew and Cook (1909b, pp. 362, 363). Additional data regarding deposition, distribution and correlation are given in the present paper. McKenna's (1965) review and analysis of published statements about the stratigraphy of the Sheep Creek Formation after 1909 is an important supplement to the present discussion.

McKenna (1965, pp. 10, 11) stated: "At its type locality [SE. $\frac{1}{4}$], sect. 30, T. 26 N., R. 55 W. (Osborn, 1918, pp. 17, 102; selected by subsequent designation by Elias, 1942, p. 126), the

Sheep Creek is overlain by channels of the type (Upper) Snake Creek Formation, there being no intervening Lower Snake Creek beds reported at that particular locality. Elias (1942, pp. 128-132) subdivided the Sheep Creek Formation . . . into two rock units. The lower unit was named the Spottedtail Member and 'includes all rocks originally included in the Sheep Creek by Matthew and Cook (1909) except the uppermost 10 to 20 feet in the midst of which is the dark-gray volcanic ash. These uppermost beds are differentiated from the Spottedtail by quite different remains of grasses and by a lithologic change which follows an apparent hiatus in sedimentation.' "

Elias (1942, p. 126), in citing the type section as the "head of West Kilpatrick Draw, or West Draw of Matthew and Cook (Matthew, 1924a, fig. 1, p. 64)," stated that Cook had taken him "to this and other gullies of the type locality of the Sheep Creek in 1933." Cook (MS) made many references to "West exposures," but did not mention *Aphelops* Draw by that name. Elias's section could not have been taken in West Draw (fig. 2) where no such exposures are present, but could have been made in *Aphelops* Draw, where his section can be nearly duplicated. Elias's (1942) type section in "West Draw" was an apparent misnomer for *Aphelops* Draw; therefore, as first revisors, we designate the type section of the Sheep Creek Formation to be in *Aphelops* Draw in the E $\frac{1}{2}$, E $\frac{1}{2}$, Sect. 30, T. 26 N, R. 55 W, Sioux County, Nebraska (fig. 6). (See Amer. Comm. Strat. Nomen., 1970, Art. 34, [iii].)

Elias (1942) made an artificial division in the Sheep Creek Formation between his lower Spotted Tail Member and his upper Sand Canyon Member, presumably at a brown sandstone layer (elevation, 4912 feet, present paper, fig. 6) in *Aphelops* Draw, but his stratigraphic section was generalized and the exact position of this contact cannot be determined.

We do not accept Elias's (1942) assignment of the upper 20 feet of the type Sheep Creek Formation (including the dark bluish gray volcanic ash) to his much younger Sand Canyon Member (with its sooty black volcanic ash) 55 miles east of the type Sheep Creek rocks. Elias's (1942) correlation was based on the presence of iden-

tical fossil grass seeds (*Stipidium dawesense alpha*, mut.), and the dark color of the ashes from the two localities. Not only are the ashes dissimilar in all but color, but Galusha's (1975, p. 50) statement that the fossils from the Sand Canyon type area and the Lower Snake Creek beds are "manifestly equivalent" shows that *Stipidium dawesense alpha* was not an accurate correlator.

A. L. Lugn (1939) redefined the Sheep Creek Formation to include the "Lower Snake Creek Beds," so named by Matthew (1924a, pp. 64-72, fig. 1) to show a faunal distinction from the "Upper Snake Creek Beds." Matthew's (1924a, pp. 61-63) final interpretation of the Sheep Creek and "Snake Creek" beds that represented "different facies of the same formation or sequence of strata, in part contemporaneous, rather than two distinct formations" probably influenced later workers (viz., A. L. Lugn, 1939; Elias, 1942; Schultz and Falkenbach, 1941, 1968) who thought that the Sheep Creek rocks should include the rocks (Olcott Formation) that contain the Lower Snake Creek Fauna. Lugn's (1939, p. 1255) lithology was applicable to both the Late Hemingfordian Sheep Creek and the Early Barstovian "Lower Snake Creek" rocks. He failed to recognize the extensive erosional hiatus that separates the Sheep Creek Formation from the overlying "Lower Snake Creek beds." The Sheep Creek Formation with its consolidated sandstone layers, silts, clays, and sequence of distinctive dark-colored volcanic ashes is unlike the "Lower Snake Creek beds" with unconsolidated channel deposits and lighter-colored ashes.

Distribution and Thickness. The Sheep Creek Formation was deposited in a broad (2- to 4-mile-wide) east-southeast trending paleovalley (figs. 2, 3) that had eroded into the massive gray Harrison sediments. Sheep Creek rocks do not extend laterally beyond the type area and their maximum thickness and distribution is difficult to determine because so much of the formation is eroded away, or is covered by present day sandhills. Sheep Creek sediments have not been traced to the north nor to the south of the type area, but different deposits in other places have yielded fossils that suggest biostratigraphic similarity. Some of these fossils have been found in other parts of Nebraska, as well as in California

and Wyoming, but equivalence in faunas does not constitute equivalence in lithology. (See Amer. Comm. Strat. Nomen., 1970, Art. 4 [c], 6 [b].)

The Sheep Creek Formation is not present in the Sinclair Draw area (fig. 2), notwithstanding Matthew's (1910, fig. 162) label that reads: "Miocene Sheep Creek Beds" overlain by "Pliocene Snake Creek Beds *Neotragoceras* Zone." Matthew (1924a, p. 162) also cited "Lower Sheep Creek beds, Olcott Hill" as the type locality for *Merychippus primus*, but we contend that this was an error. The outcrops in the northeast wash (fig. 5), which are the only ones exposed, belong to the "Lower Snake Creek beds" (=Olcott Formation).

A. L. Lugn (1939, p. 1255) identified the slump blocks in East *Plihippus* Draw (figs. 4C, 7) as "large blocks of Sheep Creek Formation." Prior to this Matthew (1924a, p. 63) had also identified these blocks as having tumbled down from an "overhanging bank of the Miocene formation," meaning the Sheep Creek. Neither Lugn nor Matthew had faunal evidence for their assignments, but on the basis of our fossils and lithology we have placed these sediments in the lower part of the here revised Snake Creek Formation. These sediments are present also on Olcott Hill (p. 308, figs. 4A, 4C, 5, 7).

Schultz and Falkenbach (1968, p. 414) stated that the "Sheep Creek and 'Lower Snake Creek' of Matthew and Cook [Cook was not co-author of the Lower Snake Creek term] are not mappable units, but faunal zones." Schultz and Falkenbach published no lithologic evidence for their opinion.

Love (1970, p. C73) protested against the practice of including Miocene rocks in western Nebraska and eastern Wyoming, particularly the Marsland (=Upper Harrison), Sheep Creek, and Split Rock formations under the "Arikaree Formation": "only confusion would have resulted if an already controversial name [Arikaree] were extended 300 miles westward from vaguely defined exposures to a different area of deposition in which rocks largely of a different age were derived from sources still farther west."

Tower Hill (fig. 6), in the northwest part of the area, is a key to part of the Sheep Creek deposition. One might expect to find Sheep Creek sediments on the flanks of Tower Hill at

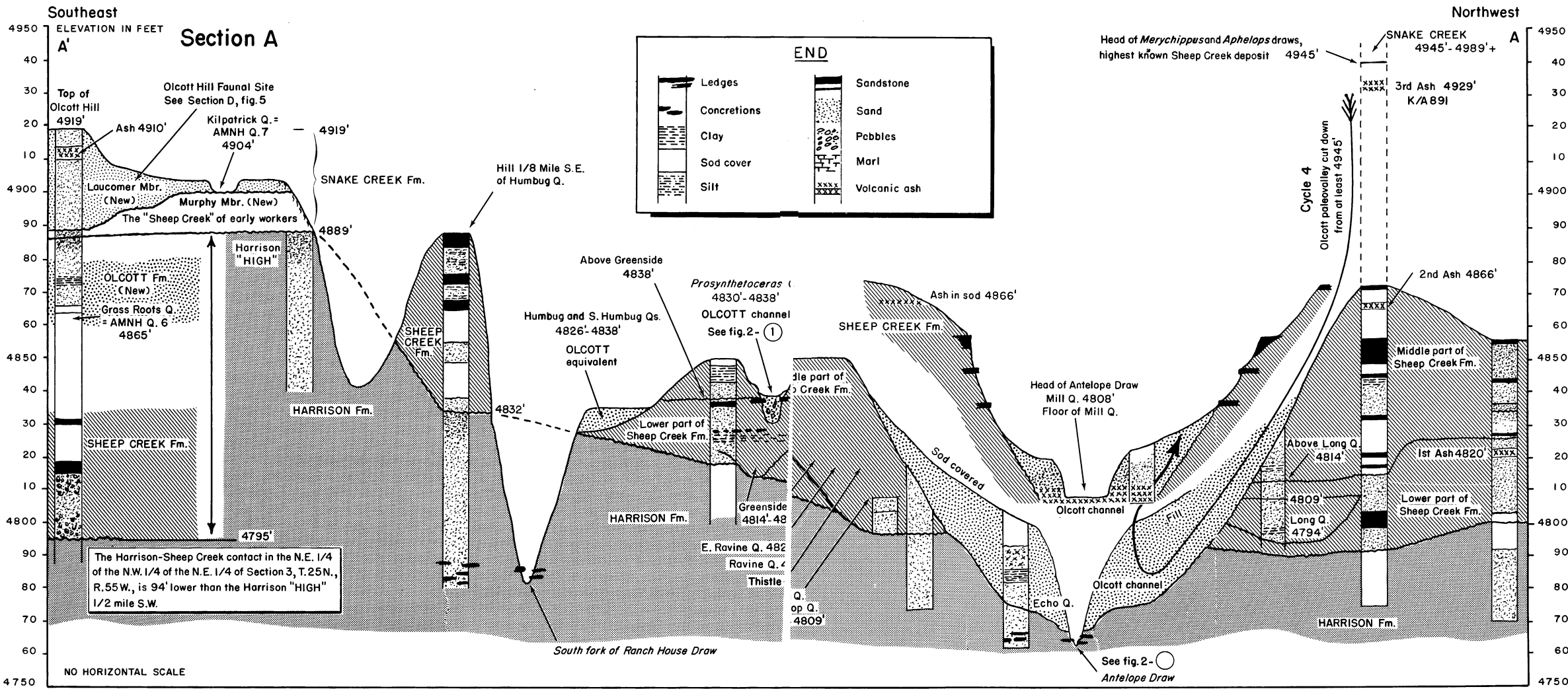


FIG. 4A. Cross sections showing relationships of late Tertiary deposits, stratigraphic position of Sheep Creek quarries and volcanic ashes, and some Olcott and Snake Creek quarries. A. *Merychippus* and *Aphelops* draws to Olcott Hill, northwest to southeast.

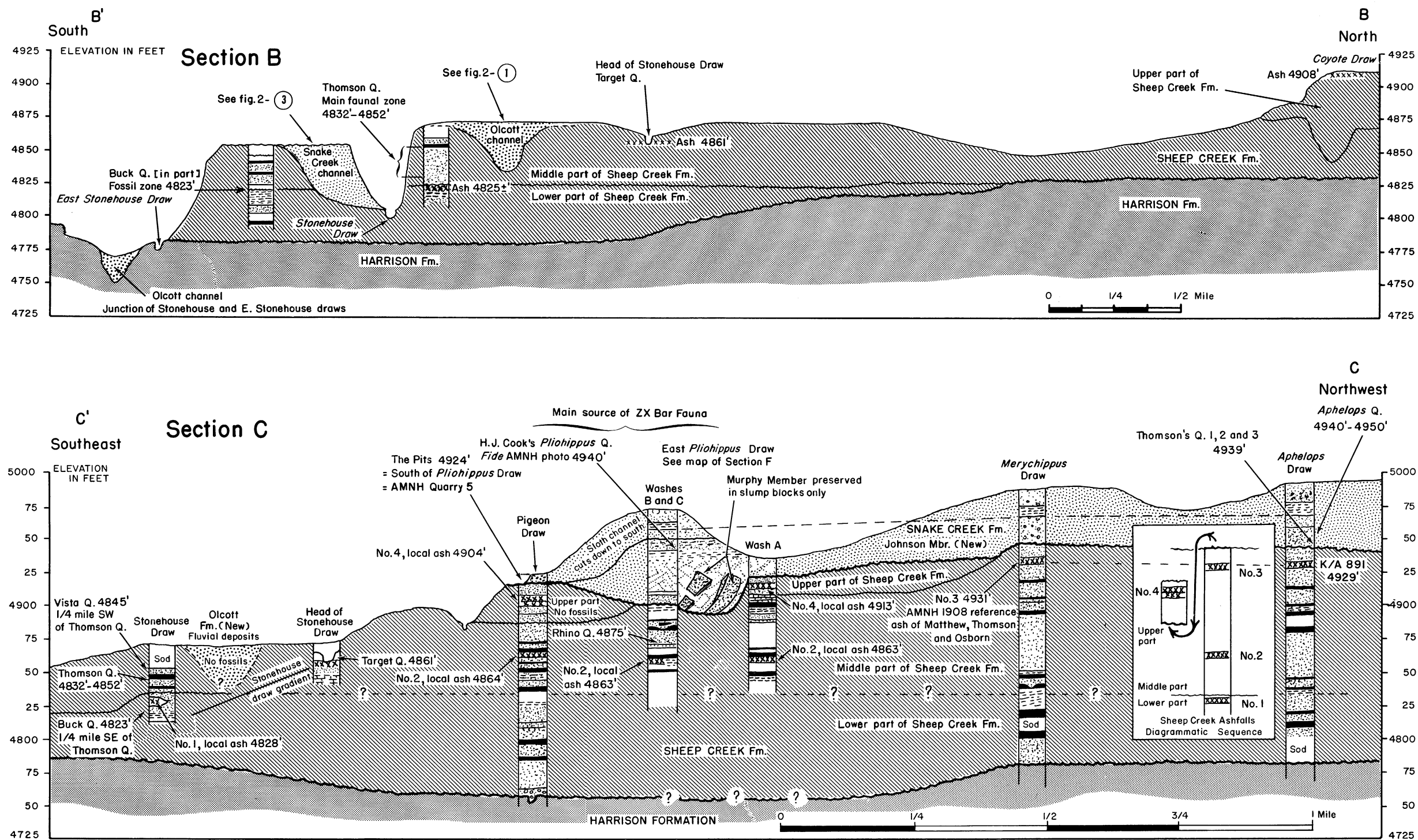


FIG. 4B,C. B. Coyote Draw to junction of Stonehouse and East Stonehouse draws, north to south.
C. *Aphelops* Draw to East Stonehouse Draw, northwest to southeast.

the same elevations as they occur in *Aphelops* and *Merychippus* draws at the head of Dry Spotted Tail Creek, but this is not the case. Tower Hill is composed of Harrison sand, overlain by Marsland Formation (=Upper Harrison). We have not identified the top 38 feet (4982-5020 elevation) of consolidated reddish sand and clay, nor have we seen similar sediments in the area. The capping 6 to 10 foot bed of hard sandstone holds up Tower Hill. The elevation of the Marsland (=Upper Harrison) is more than 5022 feet, higher than any known Sheep Creek or Snake Creek deposits to the south. The south wall of the paleovalley is not preserved, but would have been at about the same elevation as the north wall, and in the area southward toward the present Platte River valley (fig. 1B).

The Sheep Creek Formation has no lithic correlative outside of the type area, despite arguments by earlier authors (i.e., A. L. Lugin, 1939, Cady, 1940, Elias, 1942) that the Box Butte Member in Box Butte County, Nebraska, is the lithic upper part of the Sheep Creek Formation in Sioux County. Box Butte sediments were deposited on a land surface in an area different from that of the Sheep Creek Formation, and they overlie channel fills that carry a faunal complex similar to, but older than, the Sheep Creek fauna (p. 300, fig. 10). Galusha (1975) defined and mapped the Box Butte Formation as a stratigraphic unit, and in his study of the rocks and fossils of the Box Butte refuted its assignment to the Sheep Creek Formation by authors.

Lithology. The Sheep Creek Formation is here subdivided into three informally designated parts: the lower, the middle, and the upper (shown wherever present in figs. 4A-C). These subdivisions are not to be compared with Elias's (1942) three members: (1) the Spotted Tail, which is part of the Sheep Creek type rocks, (2) the unrelated Sand Canyon, and (3) the Box Butte, which is another set of rocks (p. 318).

Separation of the type Sheep Creek into three parts is based on two local erosion surfaces that occur within it. The division between the lower and middle parts is the disconformity at the base of the Thomson Quarry channel. This disconformity is not evident in the outcrops in *Pliohippus*, *Merychippus*, and *Aphelops* draws, but the position of the Thomson Quarry channel

is shown by elevations on figures 6E and 7F. The second local erosion surface may be observed in a few outcrops in *Pliohippus* Draw (figs. 4C, 7F).

The major part of Sheep Creek consists of fluvial deposits, the source of which was probably older Tertiary formations, mostly Harrison rocks. Lacustrine silts, clays, and volcanic ashes are also included in these deposits. The gray sandstone ledges that crop out in the lower and middle parts are similar in physical appearance. The upper part is composed mainly of unconsolidated massive sand.

The relative positions of the four Sheep Creek ashes, which are all bluish gray and easily confused, were not evident until the elevational controls of the stratigraphic sections were established. A comparison of numerous sections, each showing two or more ashes in superposition, provided evidence of at least four ashfalls, each of which occurs in several stratigraphic sections at about the same elevation and position. The first and second ashfalls are in lithic sequence (fig. 4A). The second, third, and fourth ashfalls are shown in their relative stratigraphic positions (fig. 4C). The Sheep Creek Ash or third ashfall, which is in the middle part of the Sheep Creek Formation (p. 299), has been dated both by potassium argon and fission-track methods.

The Lower Part of the Sheep Creek Formation

The lower part is exposed on both sides of Antelope Draw, in Stonehouse, Ranch House, and Pigeon draws, in drainages on the head of Dry Spotted Tail Creek leading to *Aphelops*, *Merychippus*, and *Pliohippus* draws, and west of Snake Den Hills (figs. 2, 4A-C, 6). Long and Greenside quarries are channel deposits that have yielded a significant part of the oldest Sheep Creek Fauna (fig. 4A). Long Quarry is on the north side of Antelope Draw and Greenside Quarry is at the head of one of the west branches of Ranch House Draw (fig. 2). A conspicuous pinkish tan sandy silt overlies Greenside Quarry. These characteristic sandy silts of the lower part of Sheep Creek occur at different elevations in Stonehouse Draw, and in the drainages leading to *Merychippus*, *Aphelops*, and *Pliohippus* draws. In weathering and color the sandy silts resemble

Marsland (=Upper Harrison) sediments, a resemblance that deceived Schultz and Falkenbach (1947, p. 203) who thought that in *Aphelops* Draw, "some of the massive pinkish sands below the quarries might well represent Marsland deposits." These outcrops produced *Merychippus primus* teeth from the basal conglomerate under the pinkish sandy silts. *Merychippus primus* has never been found in Marsland (=Upper Harrison) sediments. (See present paper, fig. 6E.)

The total thickness of the lower part of the Sheep Creek Formation is difficult to determine. Deposition was not continuous, but was interrupted by erosion that developed a moderate topographic relief (fig. 4A).

Where the base of the formation is exposed near Ashbrook Quarry and North and South Snake Den Hills (figs. 2, 6E), a basal conglomerate is composed of well-rounded reworked Harrison nodules in a sandy matrix. In other places, the sediments on the contact between the Harrison and the Sheep Creek formations are composed of pinkish brown sand and sandy clay. The dominant lithology of the lower part is massive, pinkish brown sandy silt and sandy clay; ledges or lenses of hard, blocky-weathering, gray sandstone alternate with beds of light-colored, non-resistant sandstone. These hard layers are not persistent but occur at varying levels as hard, sheetlike lenses.

The lowest observed ashfall (no. 1) crops out at about 4820 feet (right side fig. 4C) 1 mile northeast of Antelope Draw at the base of deposits on an isolated hill where an excellent exposure of Sheep Creek sediments may be seen resting on the Harrison Formation. A thin ash bed below Thomson Quarry in Stonehouse Draw at 4828 feet (left side fig. 4C) may or may not be the same ashfall, but is at about the same elevation.

Where the base of the Sheep Creek Formation is exposed in the type area at Ashbrook Quarry, North Snake Den Hill, *Merychippus* Draw, and a locality 1½ miles northeast of the Harrison "high" (figs. 4A, 6E), the lower part of Sheep Creek invariably rests with an erosional unconformity on the Harrison Formation. A lengthy hiatus separates the Harrison Formation with its Arikareean fauna from the Sheep Creek Formation with its Hemingfordian fauna.

The Middle Part of the Sheep Creek Formation

The middle part comprises the classic deposits that authors, students, and collectors refer to as "Sheep Creek." The faunas of the middle part stand for the Late Hemingfordian land-mammal age. For more than a half-century collectors from virtually every expedition have used Sheep Creek Ash that occurs near the top of the middle part as a landmark and reference point. Through common usage Sheep Creek Ash has acquired the status of a formal name and is so used herein. In the suite of four ashes that are present in Sheep Creek sediments Sheep Creek Ash is number 3, indicating its position in reference to the four known volcanic ashfalls. Sheep Creek Ash marks the upper limit of the middle part of the Sheep Creek Formation and postdates nearly all the Sheep Creek fossil sites.

The middle part of the Sheep Creek Formation is best exposed in Stonehouse, East Stonehouse, Antelope, and Ranch House draws and also crops out at the head of *Aphelops* Draw, in East *Pliohippus* and *Merychippus* draws. Fluvatile deposits just above the disconformity between the lower and middle parts have yielded the large fossil collections stored in the Department of Vertebrate Paleontology and the Frick Collection in the American Museum.

Skinner's (MS) field term for the middle part is the "Thomson Quarry faunal zone." In the present paper these deposits are referred to as the "Thomson Quarry channel." Matthew's (1924a, pp. 71, 84) "*Merychippus primus* faunal zone" was based on the fauna from Thomson Quarry in Stonehouse Draw (fig. 4A-C), 1¼ miles southeast of *Aphelops* Draw. Matthew (1924a, p. 71) described the *M. primus* zone as being in "the lower part of the Sheep Creek beds" in a "channel-bed facies of the formation [in] 'Stonehouse draw'." Matthew (1924a), of course, knew nothing of the lower part of Sheep Creek, the faunas from Greenside, Long, Ashbrook, and the small faunal site in the basal conglomerate of Sheep Creek from outcrops near Snake Den Hills (fig. 6E). Collections from these quarries were made many years later.

The elevations of various quarries in the middle part are shown on figure 4A-C: Hilltop

and East Hilltop, 4799 to 4809 feet; Above Long Quarry, 4814 feet; Thistle and Ravine, 4821 feet; East Ravine, 4822 feet; Above Greenside Quarry, 4838 feet, and Vista, 4845 feet. These quarries carry the same faunal complex with fossils similar to those from Thomson Quarry (4832-4852 ft.). Approximate elevations for the types of *Merychippus primus*, *M. secundus*, *M. tertius*, *M. quartus*, and *M. quintus* are shown on figure 6E. Thomson collected these specimens and referred their sites to Sheep Creek Ash at the head of *Aphelops* Draw.

At Long Quarry near the mouth of Antelope Draw (fig. 4A-C) the fluvial deposits of the Thomson Quarry channel readily define the base of the middle part where it overlies the lower part of the Sheep Creek Formation. Here the faunal sequence from the lower and middle parts can be shown lithically in one outcrop.

Exposures of the middle part of the Sheep Creek Formation below the slump block area in East *Pliohippus* Draw are less than a mile southeast of *Merychippus* Draw and the type exposures in *Aphelops* Draw. The pronounced variability of the sand, clay, and ashes that occurs within a short distance is illustrated on either side of section F (fig. 7). The section on Wash A (fig. 7) covers a horizontal distance of 1100 feet north by northwest, whereas the section on Wash C (fig. 7) covers a distance of only 500 feet in a northeasterly direction. The stratigraphic sections were started at the same point—the junction of recent washes A and C. The elevations of Thomson and Target quarries have been added to figure 7F for convenient reference.

The dominant lithology of the middle part is gray, buff-white to pink-tan consolidated sand with beds of white clay and prominent cemented sandstone lenses that weather out as rocky ledges. These sandstone lenses may represent secondary cementation caused by water table fluctuation after deposition.

Two ashes occur in the middle part. The lower, or number 2, ashfall (here described for the first time, fig. 4A-C) is exposed in *Pliohippus* and Pigeon draws; small clasts of volcanic ash are present in Thomson Quarry sediments, but these clasts cannot be assigned firmly to either of the ashes in the middle part. Near Antelope Draw the second ash crops out at 4866 feet elevation (fig.

4A) and is recognized in several other stratigraphic sections throughout the study area, at elevations from 4861 to 4877 feet (figs. 4B,C, 7F). Sheep Creek Ash, or number 3, crops out in *Aphelops* and *Merychippus* draws, but is not present near Antelope Draw, having been removed during the current erosion cycle. It is shown (fig. 4A) at the elevation at which it occurs in *Aphelops* and *Merychippus* draws (4929 and 4932 feet, fig. 6E).

Matthew and Cook (1909, p. 303) referred to Sheep Creek Ash "as dark gray . . . two feet thick." A. L. Lugin (1939, p. 1256) assigned the "distinctive dark-gray volcanic ash 2 to 3 feet thick" to the upper part of Sheep Creek which he interpreted as "lower Snake Creek." Elias (1942, pp. 130-131) used the Sheep Creek Ash and "identical fossil fruits" to correlate his Sand Canyon Member with the Sheep Creek Formation. Immediately underlying the Sheep Creek Ash in the type locality in *Aphelops* Draw (fig. 6E) is a bed of fine, compact, pink-tan sand that overlies the hard layer of brown, pitted sandstone that Elias (1942, p. 128) also referred to his Sand Canyon Member some 55 miles east in Dawes County, Nebraska.

In the pioneering work of Evernden et al. (1964) the Sheep Creek Ash, KA 891 (glass) was dated at 14.7 m.y. In Izett's (1975, p. 201) opinion this age might not be reliable because it was made on "hydrated glass shards, which frequently give spurious ages." According to Izett (1975) C. W. Naeser in 1973 "determined the age of the ash at 16.1 ± 3.7 m.y. using microphenocrysts. The best age for this ash (zircon) . . . is perhaps about 16 to 17 m.y."

The dip on the base of the Sheep Creek Ash is apparent in the field but is not shown on the stratigraphic sections. The dip, which probably represents the incline of a depositional surface, is not great enough to be considered a structural feature. The effect of local erosional relief on elevations, however, is a factor that must be considered. Furthermore, the deposits below the ash do not show a similar dip.

The Upper Part of the Sheep Creek Formation

In the northwest part of the area remnants of

the upper part crop out in *Aphelops*, Pigeon, *Pliohippus*, Coyote, *Merychippus*, and West draws. Snake Creek channels and more recent erosion cycles have stripped away the upper part along the south and east sides of the study area (figs. 4C, 7F).

The upper part is composed of massive, consolidated, pink and buff sand without the sandstone ledges that characterize the lower and middle parts. Fossils have not been found in the upper part. The fourth Sheep Creek ash, or number 4, is a distinctive bluish gray, similar in physical appearance to the other three Sheep Creek ashes. Ash number 4 crops out at 4904 to 4913 feet elevation in Pigeon Draw and at the head of *Pliohippus* Draw, lower than Sheep Creek Ash (no. 3, K/A 891) at 4929 feet, due to a local period of erosion within the Sheep Creek paleo-valley (fig. 4B,C).

The remnant nature of the few outcrops of the upper part of the Sheep Creek Formation make it impossible to determine the total thickness and distribution of the sediments directly below and above Sheep Creek Ash number 4.

Age and Correlation. Sheep Creek fossils from the typical area typify the Early Miocene Late Hemingfordian age. Vertebrate fossils from the middle part of the Sheep Creek Formation have served as correlators because the faunas from the lower part, mainly those from Long and Green-side quarries, were unknown to Matthew (1918, 1924a, 1924b) and others. B. J. Wilson discovered these two quarries in 1934-1935, Skinner continued working them in the 1940s, but the collection remained mostly unreported in the Frick Laboratory, except for Frick (1937) and Schultz and Falkenbach (1947). Collections from the middle part, and particularly those from the lower part of Sheep Creek, need continued study. We know of no fossils from the upper part of the Sheep Creek.

Matthew (1918, p. 183) thought that the faunas (i.e., of the middle part) were "equivalent to or slightly older than the Mascall and Deep River of Montana, distinctly older than the Pawnee Creek beds of Colorado." Osborn (1918, pp. 16-17) believed that Sheep Creek faunas compared well with those from Phillips Ranch and Cache Peak, Tehachapi, southern California, and credited Matthew with placing the age of the Phillips Ranch Fauna near that of Sheep Creek.

Cady (1940, p. 666) attempted to establish a definite stratigraphic relationship between the Box Butte and the Sheep Creek by biostratigraphic assignments that had no substantiating data. Cady (1940) stated that a "Sheep Creek channel was cut into the Marsland formation and filled with brick-red silt and sand from which Sheep Creek vertebrate fossils have been taken . . . Grayson Meade . . . and Albert Potter . . . were familiar with fauna taken from this channel, and are the authority for its age." If Meade and Potter supplied evidence of vertebrate taxa, Cady did not publish it.

On the strength of one specimen, the type of *Ticholeptus tooheyi*, Schultz and Falkenbach (1941, p. 84) also correlated the beds in Box Butte County, from which the type was taken, with the "Lower Part of the 'Sheep Creek' Formation," but gave no lithic confirmation. Galusha (1975, p. 61) also collected an oreodont referable to *T. tooheyi* from the type locality, which he included in his Box Butte Formation.

In reference to the fossil assemblage from the Box Butte Formation, Galusha (1975, p. 65) stated: "More than 400 fossil mammalian specimens collected since 1962 from exposures of the Box Butte Formation, when compared with several hundred specimens from the type locality of the Sheep Creek Formation in Sioux County, Nebraska, show that the Box Butte Formation contains fossils that are earlier than the earliest fossils from the Sheep Creek."

In a discussion of the age and correlation of his Split Rock Formation in eastern Wyoming, Love (1970, p. C83) stated that "The vertebrate fossils from the upper porous sandstone sequence are of middle Miocene age, the same age as those occurring in the Hemingford Group and Sheep Creek Formation of Nebraska and in the Sheep Creek equivalent in eastern Wyoming." Love (1970, p. C80) listed pollens and vertebrate fossils from the upper porous sandstone. In an earlier report Love (1961, pp. 115-122) supplied measured sections as well as faunal lists.

OLCOTT FORMATION, NEW NAME

Figures 2-5, 11, 14-17

Name and Definition. A new name, Olcott Formation, is used for a dominantly fluvialite sedimentary rock unit which, at its type locality,

is of Medial Miocene age (Early Barstovian). The name is taken from Olcott Hill (figs. 2, 17) and appears on Matthew's (1924a, fig. 1) reproduction of the USGS Nebraska Whistle Creek Quadrangle for 1899 (present paper p. 276). The type section of the Olcott Formation is on the northeast face of Olcott Hill (fig. 5D) in the NW $\frac{1}{4}$, SE $\frac{1}{4}$, SE $\frac{1}{4}$, sect. 3, T. 25 N, R. 55 W, Sioux County, Nebraska. The type locality includes Boulder Quarry at the base of the type section and 24 quarries in nearby Sinclair draws, all of which carry a Lower Snake Creek Fauna. Boulder Quarry, which was not discovered until 1942 (p. 337), was unknown to Matthew and is not to be confused with the starred (*) site on Matthew's (1924a, fig. 1) map on which he showed the discovery site of "*Hesperopithecus*" *harold-cookii*. That site is part of the here revised Snake Creek Formation and carries the Late Clarendonian Snake Creek Fauna of the Laucomer Member (fig. 5D).

Matthew (1924a) separated his "Snake Creek beds," without lithologic definition, into two faunal zones: (1) The Lower Snake Creek faunal zone (from the Olcott Formation) and (2) the Upper Snake Creek faunal zone (from the here revised Snake Creek Formation). Matthew (1924a, p. 61) thought that the Sheep Creek and Snake Creek beds represented "different facies of the same formation or sequence of strata, in part contemporaneous, rather than two distinct formations." The successive reports of Matthew (1918, 1923a, 1923b, 1924a, and 1932) show that he had not mastered the complex geology of this area in the few weeks he had, nor could he have solved it by faunal studies alone.

The lithologic difference between the Olcott Formation in the Sinclair draws, which is composed of reworked clasts of Tertiary sandstone, concretions, and almost no igneous gravel, and the Snake Creek Formation on Olcott Hill that carries gravel of Rocky Mountain provenance escaped the notice of Matthew and other early workers (i.e., Cook, Sinclair, Thomson).

A key to the misunderstanding of the rocks is in a 1908 photograph (AMNH 18359) that Matthew (1910, fig. 162, pp. 353-356) used in a description of the area and in a faunal list. Matthew labeled the lower deposits "Miocene Sheep Creek Beds" and the overlying sediments "Pliocene Snake Creek Beds *Neotragocerus* Zone," and re-

ferred all the channel sand deposits in the area to the "Snake Creek beds" to show that they were different from his indurated Sheep Creek beds. The site shown in Matthew's (1910, fig. 162) photograph is clearly the east side of East Sinclair Draw (figs. 2, 15), one of the 1908 collecting sites, where neither the Sheep Creek nor the Snake Creek formations (as here restricted) are present. The beds that Matthew labeled "Sheep Creek" we here refer to the Harrison Formation, and those he labeled "Snake Creek" are the Olcott Formation containing the fauna that Matthew (1923b, p. 131) placed in the "*Merychippus paniensis* zone: Late Middle or Upper Miocene," and that Matthew (1924a) later named the "Lower Snake Creek faunal zone."

A. L. Lugen (1938, 1939), Elias (1942), Schultz and Falkenbach (1940, Wood et al. (1941), and Schultz and Stout (1961), thought that the sediments from which the Lower Snake Creek Fauna had been collected were part of the Sheep Creek Formation, but none of these authors had firsthand knowledge of the complexities of the entire area. The succession of stream channel deposits was only exposed later by extensive quarrying. Especially, these authors did not know of the outcrops in Antelope and Ranch House draws where the erosional relief between the Olcott and Sheep Creek formations is so well shown (fig. 4A). The American Museum and Princeton University collections of the early 1900s were from the Sinclair draws, Olcott Hill, and the northwest part of the area, whereas all the faunal sites in Ranch House and Antelope draws were undiscovered until the Frick Laboratory worked in the 1930s and 1940s (fig. 2). Olcott sediments in the Sinclair draws represent three minor cycles of erosion and deposition and are unrelated to the Sheep Creek sediments (present paper, p. 296).

Distribution and Thickness. The Olcott Formation is confined primarily to Olcott Hill (the type locality), Sinclair, Ranch House, and Antelope draws (figs. 2-5). The only other lithic outliers from these areas are two unfossiliferous Olcott deposits that are dissected by recent erosion in Stonehouse Draw. One is near the junction of Stonehouse and East Stonehouse draws (fig. 4B), and the second lies between Target and Thomson quarries (fig. 4C).

The Olcott Formation is not known to crop

out in the northwest part of the area on the head of Dry Spotted Tail Creek, specifically *Pliohippus*, *Merychippus*, *Aphelops*, West, Pigeon, and Coyote draws. Presumably most of the Olcott sediments came in from the southwest (fig. 3).

After Sheep Creek deposition and before the deposition of the Olcott Formation, vigorous streams cut narrow paleovalleys that laced the small Sheep Creek-Snake Creek area. At the beginning of Olcott deposition the erosional relief was at least 180 feet and undoubtedly was greater. Although the thickness of the Olcott sediments can only be estimated, the thickest known remnant is about 78 feet at the type section on Olcott Hill. The top of the Olcott Formation here is 4880 feet. It is reasonable to assume, therefore, that the elevation of pre-Olcott strata (Sheep Creek and Harrison formations) needed to form the valley walls that were to contain the Olcott sediments had to be at least 4880 feet.

Channel cuts and fills carrying fossils similar to those of the Olcott Formation are present in Dawes County some 30-40 miles northeast, south of the Pine Ridge escarpments. These channels have not been traced from Sioux County to Dawes County. On the basis of faunal similarities it is postulated that degradation and aggradation were contemporaneous in Sioux and Dawes counties during Early Barstovian time (fig. 11). Galusha's (1975) use of Elias's (1942) Sand Canyon Member of the Sheep Creek Formation in Dawes County was a temporary expedient that awaited publication of the name Olcott Formation for the Lower Snake Creek Beds. Galusha (1975, p. 50) stated: "The lithology of the Lower Snake Creek beds in the type locality in Sioux County differs from that of the type area of the Sand Canyon Member, and, although the fossils from the two sites are manifestly equivalent, it is difficult to justify correlating them as the same formation on purely rock-stratigraphic criteria, despite the presence in each of similar appearing volcanic ash beds."

Lithology. The Olcott Formation lacks the hard sandstone ledges that are so characteristic of the underlying lower and middle parts of the Sheep Creek Formation, and there is no basal conglomerate, such as that observed at the base of the Sheep Creek (fig. 6E). Gravel of Rocky Mountain provenance is uncommon in the Olcott

Formation, whereas the Snake Creek Formation that crops out in the northwest part of the area (figs. 2, 3), and overlies the Olcott Formation on Olcott Hill (fig. 5D) carries small pebble-size clasts of red granite with individual clasts of various igneous rocks up to 5 inches long in diameter, longer and coarser than any clasts of sedimentary rocks, in the Olcott Formation, except for the clay boulders within the Boulder Quarry deposit at the type section on Olcott Hill (p. 337).

The Olcott Formation at the type locality on Olcott Hill and Sinclair draws, and in Antelope and Ranch House draws (fig. 2) can easily be correlated biostratigraphically, but the nature of the sediments makes it difficult to establish bed for bed correlation. Certain lithological characters in the four closely situated sites are shared, however. The sediments of the Olcott Formation are dominantly fluvatile, massive, well-sorted buff or brown and gray quartz sand, silty sand with gray sandy ash.

Minor diastrophic movements during Olcott time are evidenced by rejuvenation and secondary cycles of erosion and filling in the Sinclair draws. Several ashfalls that crop out at different elevations in the type locality (fig. 5D) and Antelope Draw (fig. 4A) indicate that volcanism occurred throughout most of the deposition of the Olcott Formation. Although the detailed correlation of these ashfalls is not conclusive, superposition of several ash falls can be observed at the individual sites.

Olcott Hill: At the type section of the Olcott Formation, Boulder Quarry channel deposit is overlain by consolidated sand interspersed with volcanic ashes at 4825 and 4848 feet and capped by a white chalky silt, that in turn is followed by another fluvatile deposit that also carries a Lower Snake Creek Fauna. Fossils were found in the fill of a sharply defined fluvatile channel similar to channel deposits in other quarries in the area (e.g., Sand, East Sand, Echo, Jenkins). The loose, well-sorted quartz sand of Boulder Quarry contains clasts of small to large clay boulders up to 14 inches.

Sinclair Draw Area: Subcycle 1 includes Camel, Snake, Trojan, North and East Wall, and Douglas quarries. These quarries contain massive, consolidated, fine, compact, gray sandy silt that

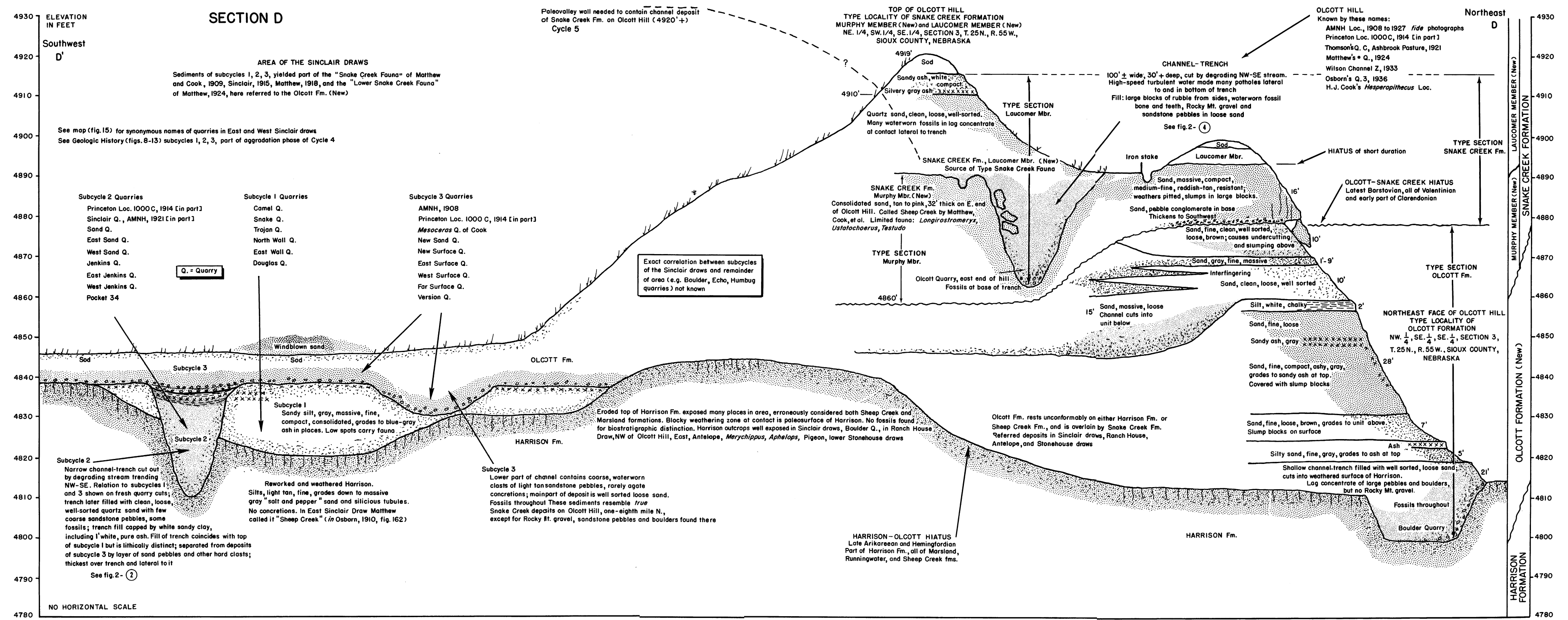


FIG. 5. D. Cross section of Sinclair draws showing (1) Olcott Formation subcycles 1, 2, 3; (2) cross section of Olcott Hill with type localities of Olcott Formation (New), and Murphy and Laucomer members (New) of the Snake Creek Formation.

grades to blue-gray ash in places. This is the first ash in the Sinclair Draw area. Lower spots carry fossils. Sediments of subcycle 1 suggest a similarity to the 28-foot unit that overlies Boulder Quarry (fig. 5D).

Subcycle 2 includes Princeton Locality 1000C (in part) and these quarries: Sinclair, Sand, East and West Sand, Jenkins, East and West Jenkins, and Pocket 34, all of which are in East and West Sinclair draws (figs. 5D, 15). A layer of fine clay and volcanic ash at the top of East Sand Quarry was separated from the overlying deposits of Surface Quarry (subcycle 3) by an erosional unconformity. In both East and West Sinclair draws the white ash that overlies the Sand quarries channel-trench (fig. 15) represents the terminal phase of subcycle 2 and precedes the faunas of the Surface quarries in subcycle 3. The working face of East Sand Quarry showed the sequence of the subcycles (present paper, p. 331). A lag concentrate of tan to pink clasts of sandstone 2 or 3 inches in diameter derived from older sediments overlies the quarries of subcycle 2.

Subcycle 3 includes these quarries: American Museum 1908, Princeton Locality 1000C (in part), *Mesoceras*, New Sand, the Surface quarries (New, East, West, and Far), and Version. The lower part of subcycle 3 is composed of well-sorted unconsolidated sand with coarse water-worn clasts of buff sandstone pebbles, and rarely agate concretions. Fossils are found throughout the deposits. Except for the Rocky Mountain gravel and boulders, the sediments of subcycle 3 resemble most the Snake Creek Formation on Olcott Hill (fig. 5D).

Antelope Draw: Antelope Draw follows the course of an ancient stream that left a narrow gorge in a paleovalley that was later filled with Echo Quarry sediments (figs. 2, 4A). Loose sand that fills the channel-trench controls the present Antelope Draw drainage pattern. Erosion resistant Sheep Creek rocks are exposed on both sides of Antelope Draw where recent erosion has removed the fill of the Echo Quarry channel.

Degradation of the ancient stream that cut the narrow gorge must have eroded through at least 180 feet of Sheep Creek Formation (4945-4770 feet elevation, fig. 4A) before cutting into the underlying Harrison Formation exposed at the mouth of Antelope Draw. Large tabular concre-

tionary layers within the typical gray sand of the Harrison Formation are now exposed along the sides of the wash.

Near the mouth of Antelope Draw a zone of cementation (a foot or less thick) is present along the base of the Echo Quarry channel at the contact with the Harrison Formation. Most of the fossils were found in a lag concentrate of clay clasts and sand pebbles. Otherwise, the trench is filled with unconsolidated, well-washed, coherent sand. The stratigraphic position that Echo Quarry occupies within the Olcott Formation cannot be determined, but its fossils agree closely with those from other Olcott quarries.

An ash in the filling phase of the Echo Quarry paleovalley occurs at about 4790 feet (fig. 4A). A quarter of a mile west at the head of Antelope Draw, Mill Quarry carries a fine sandy ash at about 4810 feet. As in Echo Quarry there is no way to associate the deposits of Mill and Floor of Mill Quarry with any of the subcycles that are exposed in the Sinclair draws. Based on biostratigraphy the Mill Quarry ash may represent the terminal ashfall in the Olcott Formation. Fission-track studies on these Olcott ashes, if they are made, may give a clue to the temporal relationships of the quarries and their fossils.

Ranch House Draw: On the hills just south of Echo Quarry, the Humbug quarries exhibit a different feature from other Olcott quarries, resting as they do partly on a Harrison "high" and partly on the Sheep Creek Formation. At this place the Sheep Creek rests against a Harrison "high" and the Humbug quarries rest directly above this contact (fig. 4A). No amount of "post-hole prospecting" showed the entire paleotopography at this place. The exposures at Humbug Quarry were small and only open to view during quarrying.

The matrix of the Humbug quarries is a fine, silty, nearly dusty, brown and gray sand that may have been derived from Sheep Creek rocks, but this is supposition, because the matrix is unlike that of Thomson Quarry in the Sheep Creek Formation in Stonehouse Draw. The fossilization of the specimens from Humbug is dominantly black-brown, noticeably different in color from those of any other quarry in the Olcott Formation.

Stratigraphic Relations. At the type section on the northeast face of Olcott Hill and in the

area of the Sinclair draws the Olcott Formation overlies the Harrison Formation with marked erosional unconformity (fig. 5D); in Antelope, Ranch House, and two local sites in Stonehouse Draw the Olcott Formation overlies the Sheep Creek Formation with less marked erosional unconformity (fig. 4A-C). At the type section the Olcott Formation is overlain by two new members of Clarendonian age of the here revised Snake Creek Formation: the older is a sedimentary rock unit (Murphy Member, new name, p. 308) that is overlain by fluviatile sediments (Laucomer Member, new name, p. 310). The type section of the Olcott Formation is the only place where a clear-cut lithic sequence of these rocks and their contained Lower Snake Creek and Snake Creek faunas can be seen.

Although Olcott sediments exposed in the Sinclair draws (figs. 2, 5D, 15) are only 1500 feet southwest of the type section on Olcott Hill, the fluviatile sediments cannot be accurately correlated from one site to the other. Neither the lithic continuity nor the lithic sequence of the Olcott Formation can be traced from the type section to the Sinclair draws, Antelope or Ranch House draws, but the faunal complex of the quarries in these sites is entirely compatible.

Stratigraphic sections made from 1941-1947 are the basis for the sections (figs. 5D, 4A-C) and the present interpretation. The stratigraphic relationships of the quarries of the Olcott Formation are presented by diagrams (figs. 5D, 4A-C), and the critical quarries are individually treated below.

The Sinclair Draw Area (figs. 2, 15). The three subcycles of minor erosion and deposition in the Olcott Formation were clearly revealed when the quarries in East and West Sinclair draws were excavated. Quarry profiles are no longer clearly defined because of subsequent slumpage. See also pages 274-275 for nomenclature of the major draws and pages 302-303 for lithology of sediments in subcycles 1-3.

West Sinclair Draw is a dry wash that has cut at nearly right angles to the directional trend of the "Sand quarries trench" (fig. 15) that contains the sediments and fossils of East Sand Quarry. In 1941 when Skinner and party opened East Sand Quarry to its maximum extent the lithic sequence of subcycles 1-3 was revealed (fig. 5D).

The "Sand quarries trench" had cut through the sandy, ash-filled silt of Trojan Quarry (subcycle 1) and through the weathered paleoland surface between the Harrison and Olcott formations (fig. 5D). The lithic succession of the Surface quarries (subcycle 3) was also open to view; the fine white clay and white ash at the top of both East and West Sand quarries are separated from the overlying Surface Quarry by an erosional unconformity that is marked by a basal conglomerate of tan to pink clasts of sandstone 2 or 3 inches in diameter. No Rocky Mountain gravel is present.

West Sand Quarry (subcycle 2) lies west of East Sand Quarry in the northwest trending up-gradient continuation of the "Sand quarries trench" (fig. 15). The present drainage cuts the trench filled by deposits of West Sand Quarry at an oblique angle, thereby exposing a working face that was longer than that of East Sand Quarry and again revealed the sequence of cutting and filling (fig. 5D).

East Surface Quarry (subcycle 3) is situated on the divide between East and West Sinclair draws and has the largest working area of any site in either draw (figs. 5D, 15). Deposits of East and Far Surface quarries rest directly on the gray ash-filled sand of Camel Quarry (subcycle 1); the intervening "Sand quarries trench" of subcycle 2 is not exposed in East Sinclair Draw (fig. 15).

Antelope Draw (figs. 2, 4A). Erosion that preceded deposition of the Olcott Formation was brought about by rejuvenation; vigorous streams cut narrow channel-trenches completely through Sheep Creek and into the Harrison Formation. Wilson in the 1930s and Skinner in the 1940s carried on extensive quarrying in Antelope Draw. Their operations uncovered a narrow, deep channel cut with nearly vertical walls showing where a rapidly flowing stream had cut its course. This ancient course can be traced where it crops out on the sides of Antelope Draw (i.e., Echo and Mill quarries, fig. 4A). Similar cuts are forming today in the valleys of the comparatively young Niobrara and Snake rivers in north-central Nebraska.

Sheep Creek sediments are exposed on both sides of Antelope Draw, whereas the Olcott Formation carrying Echo and Mill quarries is exposed in the bottom and at the head of Antelope Draw, well below the level of the Sheep Creek

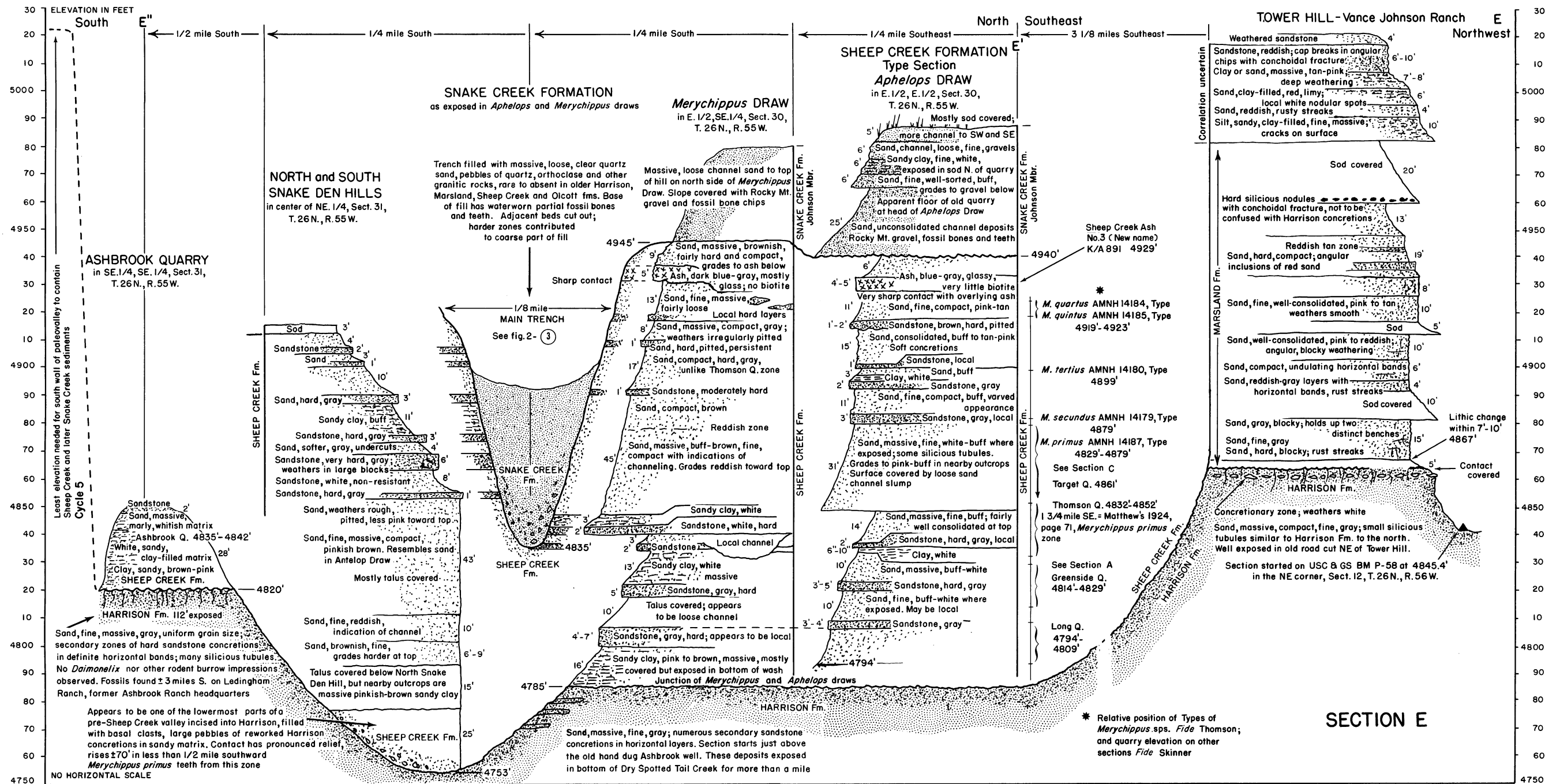


FIG. 6. E. Cross section of Tower Hill to *Aphelops* Draw, northwest to southeast; type section of Sheep Creek Formation in *Aphelops* Draw, thence north-south to Ashbrook Quarry.

outcrops (fig. 4A). Fresh exposures show that the channel containing Echo Quarry cut through two Sheep Creek quarries (i.e., Above Long, which, as its name implies, rests disconformably on Long Quarry) and into the underlying Harrison Formation. The biostratigraphy of these closely situated faunal sites is verified by lithic superposition.

The distinctly different sand texture of Long, Above Long, and Echo quarries was apparent when the quarries were opened to view. Long Quarry, which is in the lower part of the Sheep Creek Formation, has finer, browner, and more consolidated sand. Above Long Quarry, which is in the middle part of the Sheep Creek Formation, carries the same gray, buff, pinkish tan consolidated sand with rocky ledges as Thomson Quarry in Stonehouse Draw. Echo Quarry primarily contains clean, well-sorted, unconsolidated, uncemented quartz sand.

When Echo Quarry was excavated a cemented zone at the base of the fluvial filling phase of Echo Quarry was observed to be cemented to, and to overlie, the Harrison Formation. This cemented zone consists of clasts of reworked older beds and some cemented, reworked, fragmentary, well-rounded Sheep Creek fossils. The hard, black fossilization of these Sheep Creek fossils is distinctly different from the buff-colored, softer, more complete Echo Quarry fossils.

The fauna from Echo Quarry is slightly older than that of Mill Quarry which is in the upper part of the Echo Quarry channel (fig. 4A). Most of the Echo Quarry fossils were derived from elevations of 4770 to 4780 feet, whereas those from Mill Quarry were collected at an elevation of 4808 feet (fig. 4A).

Ranch House Draw (figs. 2, 4A). Humbug Quarry is situated on a grass-covered knoll and rests mostly on the lower part of Sheep Creek Formation and partly on the Harrison Formation. The matrix of Humbug Quarry, which is composed of loose, powdery clasts of reworked Sheep Creek Formation, is distinctly different from that of any other quarry in the Olcott Formation, the others having well-sorted, clean quartz sand. Although the fossil-producing zone of Humbug Quarry is from 4826-4838 feet in elevation, higher than either Echo or Mill

quarries, this does not imply that Humbug Quarry is younger. The position of Humbug Quarry in the Olcott Formation is not known but is illustrated as conceived in figure 4A. The fossils (i.e., horses) seem to be slightly older than those from either Echo or Mill quarries.

Prosynthetoceras Quarry (figs. 2, 4A) is in a narrow channel filled with unconsolidated, well-sorted sand with large clasts of sandstone 2 or 3 feet in diameter. This channel or fill does not seem to relate to other channels in the Antelope Draw. *Prosynthetoceras* Quarry directly overlies Greenside Quarry, which is in the lower part of the Sheep Creek Formation, showing yet another example of lithic superposition in the area.

Humbug and *Prosynthetoceras* quarries in the Olcott Formation and Greenside and Ravine quarries in Sheep Creek Formation are all situated within $\frac{1}{8}$ of a mile of each other (fig. 2). The complexity of deposition in this area, with the channeling, rechanneling, and filling is unique even within the Sheep Creek-Snake Creek area.

Age and Correlation. In the early 1900s the age of the Lower Snake Creek Fauna perplexed paleontologists because the fossils were mostly surface finds collected indiscriminately from Olcott Hill, Sinclair Draw, and *Aphelops* Draw where both the Snake Creek and Olcott formations were present. Matthew and Cook (1909b, pp. 361-365) wrote about the "very imperfectly known" Pliocene mammals of North America, about the diverse opinions on fossils from this epoch held by Leidy, Marsh, and Cope, and about their (i.e., Matthew and Cook, 1909b) Early "Pliocene" Snake Creek Fauna that apparently included such disparate forms as *Parahippus*, *Merychippus*, *Neotragoceros*, and *Hippidium*. Additional collections and Merriam's work on Late Tertiary fossils from the Pacific Coast led Matthew (1918, pp. 183-184) to consider the possibility of a "Snake Creek fauna [that] might in fact be a composite and not all of the same age."

The first workable plan for separating the Lower Snake Creek Fauna from the earlier and later faunas in the Sheep Creek-Snake Creek area was given by Osborn (1918, p. 28, *vide* Matthew) when he published Matthew's three "faunal zone groups" based on fossil horses: (1) from the "*Merychippus* Pockets" (=Sheep Creek Forma-

tion); (2) from "Later Pockets" (=Olcott Formation) and (3) from "Upper Pockets" (=here revised Snake Creek Formation). At that time Osborn (1918, p. 28) predicted that Matthew's "faunal zone grouping may subsequently be found to conform with a geologic grouping."

Matthew (1924a, p. 71) presented the first definitive correlation for his Lower Snake Creek Fauna: These were vertebrate fossils from the Mascall of Oregon, Phillips Ranch in the Tehachapi Mountains, Hayden's 1853 collection from the Bijou Hills, South Dakota, and fossils from the Pawnee Creek Beds of Colorado, all of which, with additional faunas and stratigraphy, agree with present-day opinions.

Tedford et al. (MS) in an evaluation of some North American Mammal Ages correlated the Lower Snake Creek Fauna from the Early Barstovian Olcott Formation with faunas from Galusha's (1975) nearby Observation and Survey quarries, and sites in Pepper Creek and Sand Canyon, Dawes County, Nebraska. The rocks from which these faunas were taken, however, cannot be lithically correlated with the Olcott Formation (see Galusha, 1975, p. 50).

Correlates in California are the Dome Spring faunas (James, 1963) from the Cuyama badlands and the Green Hills faunas, a lower assemblage from the Barstow Formation in the Mojave Desert. In Oregon, the best comparisons are with lower assemblages of fossils in the Mascall and Sucker Creek formations, and in northeastern Colorado with the Eubanks Local Fauna in the lower part of the Pawnee Creek Formation (Galbreath, 1953). An undescribed fauna of the Skull Ridge Member, Tesuque Formation (Galusha and Blick, 1971) also correlates with the Lower Snake Creek Fauna. On the Texas Coastal Plain, the artiodactyls in the Trinity River Local Fauna compare particularly well with those from the Lower Snake Creek (Patton and Taylor, 1971). Others in this general area are the Moscow Local Fauna and the Point Blank Fauna.

OGALLALA GROUP

THE SNAKE CREEK FORMATION

Figures 2-7, 12-14, 17

Name and Definition. In the present paper the Snake Creek Formation is restricted to deposits

that disconformably overlie the Olcott Formation and other rocks, and contain the Early and Late Clarendonian faunas, the Early Hemphillian *Aphelops* Draw Fauna, and the Late Hemphillian ZX Bar Local Fauna. As revised, the Snake Creek Formation contains three new members: (1) The Murphy Member, type section on Olcott Hill (fig. 5D); (2) the Laucomer Member, type section also on Olcott Hill (fig. 5D), and (3) the Johnson Member, type section in East *Pliohippus* Draw (fig. 7F).

In the northwest part of the area the main outcrops of the Snake Creek Formation are present in *Merychippus*, *Aphelops*, *Pliohippus*, and West draws on the head of Dry Spotted Tail Creek (figs. 2, 3). Outside the study area Snake Creek sediments (lower part of Johnson Member, p. 311) crop out sparsely for at least 6 miles southeast and then become covered by the Sand Hills. About 3 miles southeast of the study area Snake Creek rocks crop out where gravel-covered hills outline the general course of an ancient stream. Rounded pebbles of Rocky Mountain gravel up to 5 inches long are found on the weathered surface; red granite seems to be the major component of these coarse channel deposits. A few bone fragments on these well-covered slopes serve to associate these rocks with those of the study area.

Development of the Snake Creek Concept. The absence of a layer-cake sequence of strata in the Sheep Creek-Snake Creek area, the misleading similarity of two temporally disparate fluvial deposits in one small area (viz., the Barstovian Olcott Formation and the Clarendonian and Hemphillian Snake Creek Formation), the minimal needs of early 1900 field data, and Matthew's (1910, fig. 162) unfortunate mislabeling of a photograph of Olcott sediments in East Sinclair Draw as "Miocene (Sheep Creek beds) overlain by a Pliocene (Snake Creek) formation" (present paper, p. 301), were all factors contributing to the confused Sheep Creek-Snake Creek nomenclature and misunderstanding of the geology.

Matthew and Cook (1909b, pp. 361-362) believed that the unconsolidated fluvial deposits on Olcott Hill, in the Sinclair draws, and in *Pliohippus* Draw, were one lithic unit, and that the fossils from these places represented the "Snake Creek Fauna": "The new fauna represents over

fifty species, mostly closely allied to those of the Upper Miocene, but differs (1) in the presence of more advanced species . . . and (2) of certain Pleistocene or modern genera [*Neotragocerus improvisus*] not hitherto recorded from the Tertiary, (3) in the greater abundance and variety of three-toed horses, certain species of which show distinct approach to the Pleistocene *Equus* and *Hippidium*, and (4) in the abundance of gigantic camels of the genus *Pliauchenia*."

Eight of the new species that Matthew and Cook (1909b) named can only be matched by fossils from the Olcott Formation and are a part of the Lower Snake Creek Fauna (p. 345). These are *Monosaulax curtis*, *Tomarctus hippophagus*, *Amphicyon amnicola*, *Bassariscus antiquus*, *Merychys relictus*, *Blastomeryx elegans*, *Merycodus sabulonis*, and *Aepycamelus procerus*. The remaining species, new and referred, are best matched by fossils from the three new members of the Snake Creek Formation. Matthew's and Cook's (1909b) "new fauna" represented fossils from Early Barstovian, Early and Late Clarendonian, and Early and Late Hemphillian rocks.

In a faunal correlation of the Cordilleran Tertiary, Matthew (1915, pp. 412, 413) indicated that the Snake Creek was part of the "Ogallala of Darton" in the early part of the "Pliocene" and showed the Snake Creek and Republican River faunas of Nebraska as correlates of the European Pikermi, Samos, and Eppelsheim *Hipparion* faunas.

Sinclair (1915, pp. 73-95), following Matthew and Cook (1909b), made no distinction between the Olcott and Snake Creek rocks, but he stressed the "marked erosional unconformity" between the "Snake Creek" and Sheep Creek beds. Princeton's 1914 Locality 1000C included the Sinclair draws that carried the Olcott Formation and the Olcott Hill that carried the Murphy and Laucomer members of the revised Snake Creek Formation (pp. 308-310). It is extremely unlikely that Sinclair or his assistants, Whitford and Barner, discovered fossils in the Olcott Formation on the northeast face of Olcott Hill (i.e., Boulder Quarry, p. 337).

Matthew (1918, pp. 183-184) remarked that "The exact nature of the Snake Creek deposits was not very clear; they were obviously river-channel deposits, but in some of the outcrops the fossils and coarse material appeared to be partly

remanié," and then went on to state that Merriam's "later Tertiary faunas of the Pacific Coast . . . has afforded evidence strongly suggesting that the Snake Creek fauna might in fact be a composite and not all of the same age . . . [possibly] different fossiliferous pockets . . . ranging in age from late Miocene to early Pliocene."

Cook (1922c) indirectly made the first published reference to a type locality for the Snake Creek Formation on the label of a package containing the holotype of "*Hesperopithecus*" *haroldcookii*. Osborn (1922, p. 2) quoted from Cook's label: "One molar Tooth, ?Anthropoid, No. HC 425, Collection of Harold J. Cook, Agate, Nebraska. Found in Upper Phase of Snake Creek Beds, Typical Locality, in position in gravels with other fossils." Matthew (1923a, p. 11) supplied a geographic site and lithology: "This specimen was found . . . in the upper level of the Snake Creek quarries at a point which has been named Olcott Hill." (See Laucomer Member, p. 310, fig. 5D.)

If the dual nature of the rocks had not revealed itself to Matthew, the additional fossils at least showed that there were marked temporal differences in the faunas. Matthew (1923b) recognized four faunal zones in his "Snake Creek fossil quarries." The first two are the Sheep Creek *Merychippus primus* zone and the Lower Snake Creek *Merychippus paniensis* zone. The third, the *Hipparion affine* zone, is represented in the Snake Creek Fauna from the Laucomer and Murphy members of the Snake Creek Formation (pp. 308-310), and the fourth, the *Pliohippus leidyani* zone, is represented in the Early Hemphillian *Aphelops* Draw Fauna and the Late Hemphillian ZX Bar Local Fauna of the Johnson Member of the Snake Creek Formation (p. 311).

In his list of faunas Matthew (1924a, pp. 65-68) recognized only the first three of the four faunal zones that he had previously conceived (Matthew, 1923b). Ostensibly, because of the scarcity of fossils, Matthew abandoned his fourth (*Pliohippus leidyani*) zone and placed *P. leidyani*, *Neotragocerus improvisus*, *Megatylopus gigas*, *Megalonyx curvidens*, and *Merycodus altidens* (see present paper, p. 358) in the "Upper Snake Creek *Hipparion affine* zone."

Cook (1912, p. 8) cited "the inaccurate data kept by early collectors as to precise localities and levels of the occurrence of any fossil" as the

main reason that many Sheep Creek and Snake Creek species were not given more accurate temporal assignments. Cook and Cook (1933, p. 42) gave the "complexity of bedding and deposition of the various phases of the Upper Sheep Creek and Snake Creek beds, and the undoubted mixture of faunal elements in collecting from this zone" as reasons for grouping the "horizons and faunal elements" together, mostly under the "Lower Snake Creek." In an illustration of Tertiary formations in Nebraska, Cook and Cook (1933, p. 44) showed the sequence of "Lower Sheep Creek, Upper Sheep Creek, Lower Snake Creek, and Upper Snake Creek" implying by their position in the column that these terms represented rocks. No lithic descriptions were given although generalized correlations were made. Cook and Cook (1933, p. 43) stated: "Evidence available indicates that the Snake Creek beds will probably show at least three determinable Pliocene phases . . . [and] careful systematic collecting in the region about Valentine, Nebraska, by R. A. Stirton, Paul O. McGrew and others . . . indicate that at least three faunal phases are present in that region" one of which would "agree closely with the phase of the Snake Creek Beds in which the type of *Hesperopithecus* was found."

Frick (1937, p. 7) had access to a great number of additional "Snake Creek" fossils as well as Wilson's (MS) stratigraphic studies, but he avoided "Attachment of formation names to the localities, deposits or quarries," and preferred the use of "*Hipparion* zone" for his "Snake Creek" specimens. Frick (1937, p. 8) stated that "The channel faunas of the Nebraskan Upper Snake Creek and Xmas zones [i.e., Xmas, Kat quarries in the Ash Hollow Formation of north-central Nebraska], like the faunas of Thousand Creek, Nevada, and the Upper Rio Grande, New Mexico, may have slightly preceded those of near Blanco Uppermost Tertiary age."

Schultz and Falkenbach (1941, p. 21) regarded the "Upper Snake Creek" beds as referable to the Ash Hollow Formation or its equivalent, reasoning that "both lower and upper Ash Hollow deposits are represented in the 'Upper Snake Creek' " because of the presence of *Uta-tochoerus major* and the earlier occurring *U. profectus*.

Finally, Wood et al. (1941, p. 32) could add nothing to the clarification of the Snake Creek problem on the grounds that the "unreliability of the field records regarding these complicated channel deposits" made the Snake Creek unsafe to use for correlation.

MURPHY MEMBER OF SNAKE CREEK FORMATION, NEW NAME

Figures 3-5; 7

Name and Definition. A new name, Murphy Member, is used for a sedimentary rock unit that is unconformably overlain by the unconsolidated fluvial sand of the Laucomer Member (New) of the Snake Creek Formation. On the basis of the fauna the Murphy Member is Early Clarendonian (Medial Miocene). The type section is on the northeast side of Olcott Hill in the NE $\frac{1}{4}$, SW $\frac{1}{4}$, SE $\frac{1}{4}$, sect. 3, T. 25 N, R. 55 W, Sioux County, Nebraska (fig. 5D), near the Murphy ranch for which the new member is named. The name, Murphy, is on the Landowners' map (fig. 17) and the 1963 Sioux County Plat Book.

The misconception that the Murphy deposits are a part of the Sheep Creek Formation started in 1908. Two photographs (AMNH 18358 and 18360), showing the initial opening of deposits on Olcott Hill are labeled, "Snake Cr. (Residual) overlying Sheep Cr. beds (Lower Pliocene and middle Miocene) 20 mi. S. of Agate, Nebr." Matthew (1924a, p. 162) strengthened this misconception when he mistakenly cited the type locality for *Merychippus primus* Osborn (1918), as the "Lower Sheep Creek Beds, Olcott Hill." (See present paper, p. 296.)

From 1908, and as late as 1958, Cook's prospecting on the northeast face of Olcott Hill yielded a few fossils, some of which came from the windblown dump of the Frick Laboratory Boulder Quarry. Cook (MS) gave these data for two horse rami (HC 912 = AMNH 83445 and HC 913 = AMNH 83446) that compare well with Lower Snake Creek fossils: "found in a loose, sharp sand channel deposit, on the north side of Olcott Hill, at least 100' below the base of the Snake Creek channel on top of Olcott Hill,—where *Hesperopithecus* was found,—so it is a younger deposit, that is more deeply cut into the Sheep Creek beds, that are high on this hill under

the top Snake Creek deposits." Cook was mistaken in his lithic identification and was obviously perplexed at finding Lower Snake Creek fossils at the base of Olcott Hill. By maintaining that the consolidated pinkish tan sand (Murphy Member) was part of Sheep Creek, it was then necessary for him to refer the gray consolidated 28 foot unit (Olcott Formation, fig. 5D) below the pinkish tan sand to the Sheep Creek Formation as well. That Cook (MS) believed this to be so is shown by his data for HC 1131 =AMNH 6602: "Fish. Part Lower Jaw. Sheep Creek beds; approx. 75' below *Hesperopithecus* level (Snake Creek Beds) on the north side of Olcott Hill."

The slump blocks of Murphy sediments on the head of East *Pliohippus* Draw (fig. 7F) have also been identified as the Sheep Creek Formation. Matthew (1924a, pp. 62-63) stated: "At one or two points the channel evidently undercut an overhanging bank of the Miocene formation [viz., Sheep Creek], which has tumbled down in large blocks, the interspaces between which are filled up with coarse sand, pebbles and fossil teeth and bones."

A. L. Lugen (1939, p. 1255) reasoned that "mixed faunal lists accounted for the misidentification of Sheep Creek rocks as Snake Creek and stated: "Much of the Miocene 'Snake Creek' . . . seems to be in part not Snake Creek at all but Sheep Creek channel beds . . . Also some of the Miocene vertebrate fossils collected from 'Snake Creek' channel deposits have come from very large blocks of Sheep Creek formation, which were broken away from the banks of the Snake Creek streams." Lugen, however, cited no faunal evidence. Had he done so the Clarendonian age of the slump blocks would have been evident (present paper, p. 350).

Lithology. The Murphy Member is composed of consolidated pink, tan and gray sand, sandy clay, and has a basal conglomerate of sandstone pebbles. Lithologically, the Murphy Member at the type locality on Olcott Hill (fig. 5D) and the referred Murphy sediments in the slump blocks in East *Pliohippus* Draw (fig. 7F) are similar, i.e., consolidated, pitted-weathering, pink-tan sand, that in some blocks grades upward into a gray sandy clay. The slump blocks are remnants of valley walls (Murphy Member) that fell into a channel cut by a paleostream.

Distribution and Thickness. The original geographic extent of the Murphy Member cannot be determined because it is exposed locally only at the type section on Olcott Hill (fig. 5D), at a small outcrop in nearby East Draw (right side fig. 2), and in the slumped remnants of paleovalley walls in East *Pliohippus* Draw (figs. 3, 4C, and 7F). At the type section on Olcott Hill (fig. 5D) the consolidated pinkish tan and gray sand and sandy clay of the Murphy Member is 16 to 32 feet thick; large blocks of these sediments have slumped down and are embedded in the sod on Boulder Quarry.

The Murphy Member was probably much thicker than the remnant on Olcott Hill (32 feet), judging from the 78 foot differential between its base elevations on Olcott Hill (4878 feet) and in *Pliohippus* Draw (4900 feet), and may have capped all the deposits in the vicinity of Antelope Draw in Early Clarendonian time.

Sediments of the Murphy Member are so limited that little can be determined about their mode of deposition and the relief that developed after deposition is only suggested at the aforementioned sites. After deposition, however, rapidly flowing Snake Creek streams cut through the Murphy sediments and into the underlying Sheep Creek Formation.

Stratigraphic Relations. The Murphy Member is in the lower part of the Snake Creek Formation, and was deposited on the eroded surface of both the Late Hemingfordian Sheep Creek and the Early Barstovian Olcott formations. Continuous and excellent outcrops on the northeast face of Olcott Hill show the superposition of the Murphy Member on the Olcott Formation at Boulder Quarry (fig. 5D). At the type locality on Olcott Hill and in nearby East Draw (fig. 2) the Murphy Member has a basal conglomerate of sandstone pebbles in a loose sand channel. Near the top of Olcott Hill the Murphy Member is unconformably overlain by the Laucomer Member (New, p. 310).

In East *Pliohippus* Draw the slump blocks of the Murphy sediments rest on the middle part of the Sheep Creek Formation. The fill that surrounds the slump blocks is the lower part of the Johnson Member (New, p. 311), which is also in erosional contact with the Sheep Creek Formation. (Figs. 4C, 7F.)

Age and Correlation. The erosional hiatus at the base of the Murphy Member on Olcott Hill (fig. 5D) represents a period of time that encompasses Medial and Late Barstovian and all the Valentinian. The unconsolidated fluvial sand of the Olcott Formation that immediately underlies the Murphy Member on the northeast face of Olcott Hill (fig. 5D) has yielded *in situ* fossils (e.g., *Desmatippus* sp.) that can be referred only to Early Barstovian time. Fossils from the unconsolidated channel sand of the overlying Laucomer Member (New, p. 351) of the Snake Creek Formation, and those from the Murphy Member are referable to some of the same taxa.

The stratigraphic position (fig. 5D) and the limited fauna (pp. 349-351) of the Murphy Member clearly show that it is not part of the Sheep Creek Formation as early workers believed (Matthew, 1924a, p. 63; A. L. Lugin, 1939, p. 1255, and Cook, MS). In the Murphy sediments on Olcott Hill Cook (MS) found two dental fragments whose source he attributed to the "Sheep Creek beds" that underlie the Snake Creek. One is a cervid ramus (HC 432 =AMNH 83442) that can be matched only with *Longirostromeryx wellsii* from deposits of Early Clarendonian age (p. 351). The other, an oreodont maxilla (HC 1250 =AMNH 83545) was found a few yards away and compares with *Ustatochoerus major* from the Late Clarendonian Xmas-Kat quarries in north-central Nebraska (p. 350). The characteristic pinkish tan matrix of the Murphy Member adheres to both specimens. Neither taxon is known from the Sheep Creek Formation.

Four specimens with definite lithic allocation have been collected from the slump blocks in East *Pliohippus* Draw, all of which are easily referable to Clarendonian taxa; none can be compared with Sheep Creek forms. These specimens are *Hypolagus* cf. *vetus*, *Prosthennops* sp., and two specimens of *Procamelus occidentalis* (faunal list, p. 349).

Cook (MS) often mentioned a large *Testudo* shell that was once exposed near the top of the Murphy Member when he referred to his "*Hesperopithecus*" site on Olcott Hill. The shell was destroyed sometime after 1969, but fragments of it were retrieved and are now in the Frick Collection. Another turtle shell, the impression of which remained in 1973, had also been removed from a nearby site. Numerous turtle shell frag-

ments are present in the slump blocks in East *Pliohippus* Draw, suggesting a paleo-environment similar to that on Olcott Hill.

LAUCOMER MEMBER OF THE SNAKE CREEK FORMATION, NEW NAME

Type Member of the Snake Creek Formation
Figures 2-5

Name and Definition. A new name, Laucomer Member, is used for unconsolidated fluvial deposits that unconformably overlie the Murphy Member of the Snake Creek Formation (fig. 5D). On the basis of the fauna the Laucomer Member is Late Clarendonian (Medial Miocene). The type section is in the same location as that of the Murphy Member: The northeast side of Olcott Hill, in the NE $\frac{1}{4}$, SW $\frac{1}{4}$, SE $\frac{1}{4}$, sect. 3, T. 25 N, R. 55 W, Sioux County, Nebraska. The type locality is near the Laucomer ranch for which the new member is named. The name, Laucomer, appears on the Landowners' map (fig. 17).

Matthew (1923a, p. 11) set the type locality for the Snake Creek Formation when he described the discovery site of "*Hesperopithecus*" *haroldcookii* (present paper, p. 311). Fossils from the Laucomer Member make up part of the Late Clarendonian Snake Creek Fauna (p. 351).

The Laucomer deposits on Olcott Hill were sampled by most of the institutions that collected in the Sheep Creek-Snake Creek beds. The American Museum field parties collected in Kilpatrick Quarry and at the "*Hesperopithecus*" site. This was a favorite site of Cook's who used it frequently as a point of reference. The Frick Laboratory Olcott Quarry (fig. 5D) is close by the "*Hesperopithecus*" site. Princeton's 1914 Locality 1000C included Laucomer sediments on Olcott Hill as well as the Olcott Formation in the Sinclair Draw area.

Lithology. Pre-Laucomer erosion was carried on by rapidly incising, vigorous streams that cut a V-shaped trench into the weak stratum of the Murphy Member on Olcott Hill. This trench, which contains the sediments of the Olcott Quarry (fig. 5D), is 30 feet deep and about 40 feet wide at its deepest part, or V-shaped cross-section, and is filled with clean well-sorted quartz sand, small clasts of locally derived material and large blocks of Murphy sediments undercut from the sides of the trench. Well-preserved fossils

were collected from the fill of Olcott Quarry and deposits lateral to it. Excavation uncovered several deep, bowl-shaped potholes, at least 2 feet in rough diameter and depth, that were filled with coarse gravel and fossils; usually a larger grinding stone lay in the bottom of the pothole. These potholes and their contents suggest the force and velocity of the incising stream. Similar trenches are now being formed in the bed of the Niobrara River in north-central Nebraska.

At the northwest end of Olcott Hill deposits in the Kilpatrick Quarry preserve the point bar deposits of this ancient stream, whereas the deposits of Olcott Quarry on the southeast end of the channel represent the fill of the trench itself. No sign of the trench or its deposits are present in East Draw a few yards to the south (fig. 2). The north side of the trench was partly exposed by the headward eroding draw immediately southwest of Boulder Quarry (figs. 2, 3). This is directly below the "*Hesperopithecus*" site (fig. 5D).

Matthew (1923a, p. 11) supplied a geographic and lithologic description of the Laucomer Member when he described his "Upper Snake Creek" as an adjunct to Gregory and Hellman's (1923a) report on "*Hesperopithecus*" *haroldcookii*. "This specimen was found by Harold J. Cook in the upper level of the Snake Creek quarries at a point which has been named Olcott Hill, on the ranch of Mr. Harry Ashbrook, twenty miles south of Agate, Nebraska. The Upper Snake Creek . . . consists of sand, pebbles and numerous fragments of bone, forming irregular lenses, or pockets, on the eroded surface of an older formation, the Sheep Creek beds [Murphy Member, present paper, p. 308]. They [Snake Creek sediments] appear to be channel-fill lenses and extend for a distance of about three miles to the westward, cropping out at the heads of a series of little 'draws,' or dry gullies on the southwest margin of the sand-hill area between the Niobrara and North Platte valleys. Associated with the channel-beds are finer, uniform, clean sands, partly of eolian deposition [cross-bedded sand of *Plihippus* Draw, slump block area, present paper, p. 309], partly water-deposited, and varying in thickness from twenty feet to zero, covered by the sodded surface of the plains."

At the type section on Olcott Hill (fig. 5D) the Laucomer Member is characterized by friable

coarse quartz sand containing gravel of Rocky Mountain provenance, waterworn fossil bone and teeth, and large clasts of clay and sandstone. Near the crest of Olcott Hill a silvery gray ash (4910-4917 feet) overlies the Laucomer Member. This ash resembles Clarendonian (Miocene) ashes in north-central Nebraska that are present in beds referred to the Ash Hollow Formation (Skinner et al. 1968, p. 409). The period of volcanic activity that accompanied deposition of the Laucomer Member on Olcott Hill must have ceased because there is no indication of the silvery gray ash in the succeeding Johnson Member.

Distribution and Thickness. A paleostream trending from northwest to southeast deposited Laucomer sediments that vary from 4 to 47 feet thick on Olcott Hill (figs. 3, 5D). At the type section the sediments of this ancient stream are defined by Olcott Quarry on the southeast end of Olcott Hill and by Kilpatrick Quarry on the northwest end (fig. 2). The border of the channel at Olcott Quarry suggests the beginning of an east-northeasterly trending bend, but no trace of an extension of the Laucomer deposits could be found.

Stratigraphic Relations. At the type section (fig. 5D), which is the only place that the Laucomer Member is positively identified, it overlies the Murphy Member with a marked erosional unconformity.

Age and Correlation. The fossils from the Laucomer Member make up the Late Clarendonian Snake Creek Fauna (pp. 351-355). This fauna compares well with faunas from the Late Clarendonian Xmas-Kat quarries in north-central Nebraska.

JOHNSON MEMBER OF THE SNAKE CREEK FORMATION, NEW NAME

Figures 2, 3, 4B-C, 6, 7, 12-14, 16, 17

Name and Definition. A new name, Johnson Member, is used for a Late Miocene sedimentary rock unit that overlies the Sheep Creek Formation with marked erosional unconformity. The lower part of the Johnson Member carries the Early Hemphillian *Aphelops* Draw Fauna (p. 355); the upper part carries the Late Hemphillian ZX Bar Local Fauna (pp. 358-361). The type section of the Johnson Member is exposed near the head of East *Plihippus* Draw (figs. 2, 7F) in

the NE $\frac{1}{4}$, NW $\frac{1}{4}$, sect. 32, and the SE corner of the SW $\frac{1}{4}$, sect. 29, T. 26 N, R. 55 W, Sioux County, Nebraska. The Johnson Member is the uppermost member of the Snake Creek Formation. The type locality is on the Vance Johnson ranch where the best outcrops are exposed. The name, Johnson, appears on the Landowners' map (fig. 17).

Duplicate numbers for quarries, particularly those in *Aphelops* Draw, have unfortunately made the exact locality assignment for some of the Snake Creek fossils questionable. Thomson's 1918 quarries 1, 2, and 3 (fig. 16) on the head of *Aphelops* Draw are not the same as the American Museum 1908 quarries 1, 2, and 3. (See table 4, present paper.)

Distribution and Thickness. The sediments of the Johnson Member represent successive stream loads that were deposited in the Snake Creek paleovalley. At least one deep channel-trench (see Stratigraphic Relations, p. 313 and fig. 6E) with some 60 feet of fill shows that some of the sediments in the lower part of the Johnson Member were brought in by vigorous stream action. At the type section on the head of East *Pliohippus* Draw (fig. 7F) the sedimentary succession suggests a river system that left coarse gravel including red granite clasts at the base that were overlain by successive layers of channel sand and sandy clay, all of which were surmounted by massive, fine, loose sand representing a terminal phase of aggradation. Late Hemphillian fossils have been derived from these massive sands.

At the type section on the head of East *Pliohippus* Draw (fig. 7F) the Johnson Member reaches a maximum thickness of 70 feet. In the slump block section (inset map, fig. 7F), the cross-bedded sand of the lower part of the Johnson Member overlies the slump blocks (Murphy Member) and fills the interspaces to the base of the cut. Johnson outcrops at the head of *Aphelops* Draw are about 55 feet thick, and those at the head of *Merychippus* Draw are about 30 feet thick (figs. 6E, 4C). South of East *Pliohippus* Draw where the sloth channel cuts down sharply, only a remnant (6 feet thick) remains at the Pits (fig. 4C). Farther south, on the west side of Stonehouse Draw and opposite Thomson Quarry (fig. 4B), another sod-covered remnant (about 20 feet thick) is present.

Lithology. The Johnson Member is divided into two lithologic sequences (fig. 7F). The lower 32 feet of sediments are similar to those of the Laucomer Member on Olcott Hill (figs. 4A, 5D), in that they represent the deposits of fairly competent streams that had a source yielding a high proportion of red granite clasts. In the 18 feet of massive loose sand and cross-bedded sand that overlie the basal sand and gravel, no volcanic ash is present. Locally, the lower part is composed of unconsolidated sand and gravel, with clasts of red granite, medium to fine, brown to buff, cross-bedded sand with numerous included clay pebbles and other sedimentary clasts.

The following analysis of these clasts from East *Pliohippus* Draw is so pertinent that we include part of a letter from the late Daniel Yatkola (June 9, 1975) with whom we had an exchange of ideas on stratigraphic problems: "The breakdown of the Snake Creek pebbles (a total of 675) is as follows: orthoclase feldspar (red) granite and pegmatite pebbles =537; pegmatite pebbles (mostly clear quartz) =53; amorphous silica (chert) =66; lithic (looks like reworked Marsland) =8; gneissic textured pebbles =5; quartzite =1; misc. =5. The very high percentage of orthoclase feldspar granite may be somewhat weighted because I counted all the orthoclase feldspar pebbles as belonging in this class even though some of the pebbles were of obvious pegmatite origin. Pegmatite pebbles are pebbles that are made of one mineral (mainly quartz) in contrast to the granite which has many minerals in each pebble. The orthoclase feldspar rich granite from the Snake Creek gravel is very similar to the Sherman Granite in the Front Range."

In East *Pliohippus* Draw the loose sand and gravel of the lower part of the Johnson Member surrounds and overlies the large slump blocks of the Murphy Member (figs. 4C, 7F). The cross-bedded sand grades outward from the slump block area into well-sorted, loose sand and gravel derived from red granite terrain. The slump blocks are remnants of valley walls that fell into a channel cut by a paleostream.

The paleostream that cut the channel probably flowed from the south and was abruptly deflected to the southeast, forming a sharp bend. The bend is so situated that the west bank of the paleochannel is exposed near the junction of re-

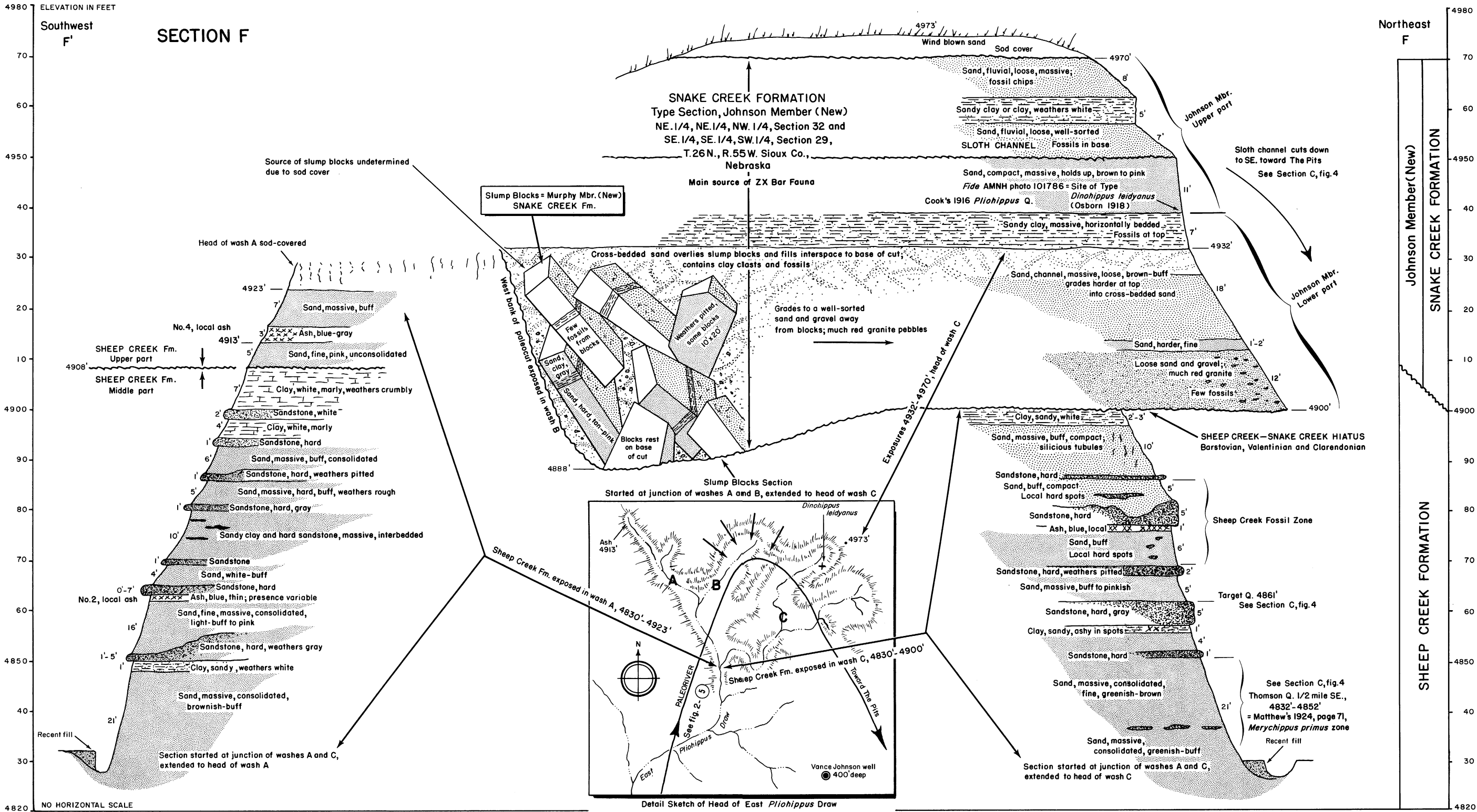


FIG. 7. East *Pliohippus* Draw and slump blocks; F. Type section of Johnson Member (New) of the Snake Creek Formation.

cent washes A and B (inset map, fig. 7F). The positions taken by the long thin slump blocks as they settled into the paleostream clearly show the nature and size of the bend where the gravity slumping occurred. In the wash labeled "B" at least 32 feet of Murphy sediments have been cut out in the bend where blocks from the valley walls slid into the ancient stream and are now weathering out. The tensile strength of the Murphy sediments that compose the slump blocks would not withstand vigorous water transport.

During the cutting and slumping a distinctive cross-bedded, sandy matrix with water-transported clay and sand pebble clasts completely covered and filled the interspaces between the blocks to the base of the channel, indicating that slumping and filling must have occurred almost contemporaneously. Matthew (1924a, p. 73) thought that these cross-bedded sands were eolian dune-sand, but failed to consider that a windblown cross-bedding fill could not have been deposited between the blocks and would not have contained water-transported clay, sand pebbles and fossils.

The looser fluvial sand exposed in washes B and C (fig. 7F inset) is thought to be the inner or point bar side of the bend of the ancient stream (Early Clarendonian). Numerous photographs of the blocks have been made, some of which are in the Department of Vertebrate Paleontology Archives in the American Museum. These blocks are textbook examples of slumped paleovalley walls.

The upper 7 feet of channel sand and clay of the lower part of the Johnson Member (fig. 7F) are also present on the head of *Aphelops* Draw (fig. 6E), where signs of past quarrying remain, presumably from Thomson's work. This same channel, although sod covered, is thought to be present in the Pits (figs. 2, 4B) where much of the Early Hemphillian *Aphelops* Draw Fauna was collected.

The upper part of the Johnson Member is composed of 31 feet of massive sand and clay. The main source of the ZX Bar Local Fauna is in the 11 feet of massive, compact, brown to pink sand. The type of *Dinohippus leidyanus* (AMNH 17224) occurred in the base of the 11-foot-thick unit at an elevation of 4940 feet, which was Mat-

thew's (1923b) *Pliohippus leidyanus* zone. These sediments are unconformably overlain by 7 feet of loose, fluvial sand that appears to cut down to the south through the underlying unit. This 7 foot channel, which carries sloth bones (see Hirschfeld and Webb, 1968), is overlain by a bed of white-weathering sandy clay surmounted by another bed of loose sand containing fossil chips.

Stratigraphic Relations. The Johnson Member overlies the Sheep Creek Formation with a marked erosional unconformity at the type outcrops on the head of East *Pliohippus* Draw (fig. 7F), in *Aphelops* and *Merychippus* draws (fig. 6E), in the Pits near Pigeon Draw (figs. 2, 4C), and opposite Thomson Quarry near Stonehouse Draw (fig. 4B). At Pigeon Draw the Johnson Member overlies the upper part of the Sheep Creek with erosional unconformity, whereas opposite Thomson Quarry pre-Johnson erosion cut through the middle part of the Sheep Creek into the lower part (fig. 4B).

Between the head of *Merychippus* Draw and North Snake Den Hill (fig. 6E) the profile of an exceptionally deep channel-trench is exposed that has cut through 100 feet of Sheep Creek sediments. Resistant rocks swept by vigorous stream action from beds adjacent to the trench make up the coarse part of the fill. The base of the fill carries red granite gravel, sand, ground bone chips, nodules of Harrison and Sheep Creek sediments, and clasts of pink silt that may have been derived from the Marsland Formation outside of the study area. Most of the fossils from this trench are fragmentary. This channel fill, which is assigned to the lower part of the Johnson Member, is unlike the conglomerate at the base of the Sheep Creek Formation that is also exposed near the trench and North Snake Den Hill (fig. 6E). These Johnson sediments somewhat resemble those of the Laucomer Member on Olcott Hill (fig. 5D), except that they lack the silvery gray ash incorporated into the Laucomer sediments. In view of the lithic dissimilarity (fine silts and clays, no volcanic ash), differential in elevation, and a later fauna, it seems reasonable to assume that the drainage system that contained the lower part of the Johnson Member was different from the Laucomer Member on Olcott Hill.

Age and Correlation. Fossils from the Johnson

Member of the Snake Creek Formation represent both Early and Late Hemphillian time. In their study of the Arikareean through Hemphillian Mammal Ages Tedford et al. (MS) correlated the Early Hemphillian *Aphelops* Draw Fauna (present paper, p. 355) with assemblages of fossils from the "upper part of the Ash Hollow Formation of

southwestern Nebraska and northeastern Colorado." In the base of the Late Hemphillian assemblage, these authors compare the ZX Bar Local Fauna (present paper, pp. 358-361) with "forms from the Optima and Coffee Ranch sites of the southern Great Plains."

REGIONAL AND LOCAL PALEOGEOMORPHOLOGY

Figures 1, 3, 8-13

The complex sedimentation of the study area (fig. 3) is intimately associated with regional events of Medial and Late Tertiary times in western Nebraska and eastern Wyoming. Processes that resulted in the fossiliferous sediments, their relationships, geographic positions and elevations, are discussed on pages 315-321 and illustrated in sections (figs. 8-13) showing the successive local cutting and filling phases of six major cycles that began in post-Arikareean time. The degradation phase of the last cycle is still in progress. The cycles of erosion and deposition did not proceed at a uniform rate (some lasted longer than others), and do not necessarily correspond to the normal, or river cycle, in which the land surface is brought to grade and then rejuvenated.

Locally, the present grass-covered area shows little evidence of the succession of the different paleodrainage systems that laced the region, nor are the processes fully understood that produced the random entrenchment and filling of the ancient valley systems. These paleodrainage systems (including present-day drainages) never reached maturity, but were in their more youthful stages when degradation stopped and aggradation began. It is likely that a complex of factors interrupted erosion and renewed deposition. Of three possible factors, the most likely is that: (1) Successive regional uplifts without structural deformation initiated degradation that was followed by regional settling and aggradation. (2) Climatic changes may have contributed to increased river competency, or increased precipitation may have resulted in grasses and forests that diminished erosion rate. (3) Unknown events that changed the base level of the downgrade part of the sedimentary basins may have initiated either renewed aggradation or degradation, although this is less likely. Today, the surface gradients of the Recent

drainage systems are as steep, or steeper, than they were during the post-Harrison periods of erosion. If this were not so, the present Platte River flowing out of the mountains would be dropping sediments in the lower part of its drainage system. As it is, none of the rivers crossing the plains from the eastern front of the Rockies is dropping its sedimentary loads.

Pre-Sheep Creek Topography. The local deposits with which we are concerned rest primarily on the Harrison Formation. This description of the geological setting, therefore, begins at the close of Harrison time when the high tableland of western Nebraska and eastern Wyoming was an undissected plain. The Harrison land surface had only slight regional relief as indicated by the profile (figs. 1B, fig. 8, cycle 1).

After Harrison time erosion of the friable Harrison sandstone produced a highly rugged topography, part of which is outlined by a caliche-weathering zone, locally known as the Agate Lime. The time interval in this period of degradation is assumed to have been long, because there is a distinct faunal change between the Harrison Formation and the superposed Marsland Formation (=Upper Harrison).

The elevational profile (1B) gives a preliminary orientation for discussions on the cycles of erosion and deposition. Details have been eliminated in order to show more than 1145 feet of Oligocene and Miocene sediments of western Nebraska, the positions of several formations discussed elsewhere in the present paper and their relationship to the recent topography. The elevations of the bench marks are the only established reference points near the area that make it possible to use the sea level datum (see Method of Elevational Control, above).

The profile (fig. 1B) covers an area that extends from about 4 miles north of the Niobrara

River southward to the south side of Sioux County, and past the Platte River to Scott's Bluff. The stratigraphic sequence of Tertiary deposits on Scott's Bluff (based on a stratigraphic section measured from the Platte River to the top of the bluff) shows the formations and elevations of the various contacts. Certain volcanic ashbeds outside of the Sheep Creek-Snake Creek area are also shown (fig. 1B) because the inclusion of the K-Ar dates, however subject to correction, aids in presenting regional relationships and stratigraphic sequence not only of the Late Oligocene but the Miocene sediments with which we are concerned.

Some of these volcanic ashes were dated by Evernden et al. (1964) during their pioneering work in the early 1960s. These authors were well aware of the limitations of the K-Ar method of dating windblown ashes and the fact that some of the dates did not fit the accepted land mammal ages and faunas. The recent fission-track method has produced dates that are in disagreement with some of the earlier K-Ar dates on volcanic glass, which have proved to be inconsistent.

Evernden et al. (1964) dated the Gering Ash (KA 985, glass) at 25.6 m.y. (see present report, fig. 1B). This ash was collected from the north face of Scott's Bluff, the type locality of the Gering Formation as designated by Osborn (1909, p. 71). The sample (KA 985) was taken from 11 feet above the local Gering-Brule contact in the upper part of the Gering Formation as it is exposed in the Platte River Valley. This ash has been incorrectly interpreted as the start of Gering time, because the lower part of the Gering Formation is not present at Scott's Bluff.

Obradovich, Izett, and Naeser (1973, pp. 499-500) dated a sample of the Carter Canyon volcanic ashbed of the Gering Formation. The ash occurs at about 40 feet above the base of the Gering Formation at Helvas Canyon south of Scott's Bluff where the lower part of the Gering paleovalley is present. The biotite in the Carter Canyon ash has a K-Ar date of 27.0 ± 0.7 m.y., and the zircons have a fission-track date of 27.8 ± 3.1 m.y. These authors also dated biotite from the same Carter Canyon ash bed at Round House Rock as 28.0 ± 0.7 m.y., and concluded that "Our age determinations indicate that the lowest part of the Gering Sandstone is 28-29

m.y. old." These dates suggest a temporal range from the lower part of the Gering Formation of 28-29 m.y. to the upper part at 25.6 m.y. (even though the radiometric dating on the ash in the upper part used glass).

AGGRADATION AND DEGRADATION IN NORTHWESTERN NEBRASKA

Figures 8-13

Six cycles of erosion and deposition in the Sheep Creek-Snake Creek area are illustrated and discussed in the following pages. Although the illustrations are diagrammatic and relevant to the northwestern part of Nebraska and not just the study area, they explain our ideas of the geographic and geologic positions of the various Tertiary formations dealt with in this report, and point out unsolved problems of differing elevations of these formations.

Less than two years after Matthew's and Cook's (1909b) report, Cook transmitted another paper in June, 1911 (published in 1915) on the geology of Sioux County, which, for its time, showed a remarkable understanding of local and regional geology. In this report Cook (1915, pp. 68-75, fig. 3) gave an idealized stratigraphic section that agrees generally with the geology of the present paper. Although Cook knew that certain fluvial deposits were present at high elevations, he did not point out that there had to be containing uplands bordering the paleovalleys before streams such as the Snake Creek could leave their loads at present day elevations. It must be remembered, however, that Cook lacked the elevational controls available to the present authors (p. 275). In his discussion as well as his illustration Cook (1915) referred to deposits that later became a part of his Running-water Formation (Cook, 1965), as they are exposed in the Whistle Creek Valley.

CYCLE 1

Figure 8

Post-Arikareean to Early Hemingfordian. Cycle 1 begins with the post-Harrison land surface on which the Marsland Formation (=Upper Harrison) was deposited. Figure 8 shows the filling phase of the first cycle. The length of time required for deposition of the Marsland Forma-

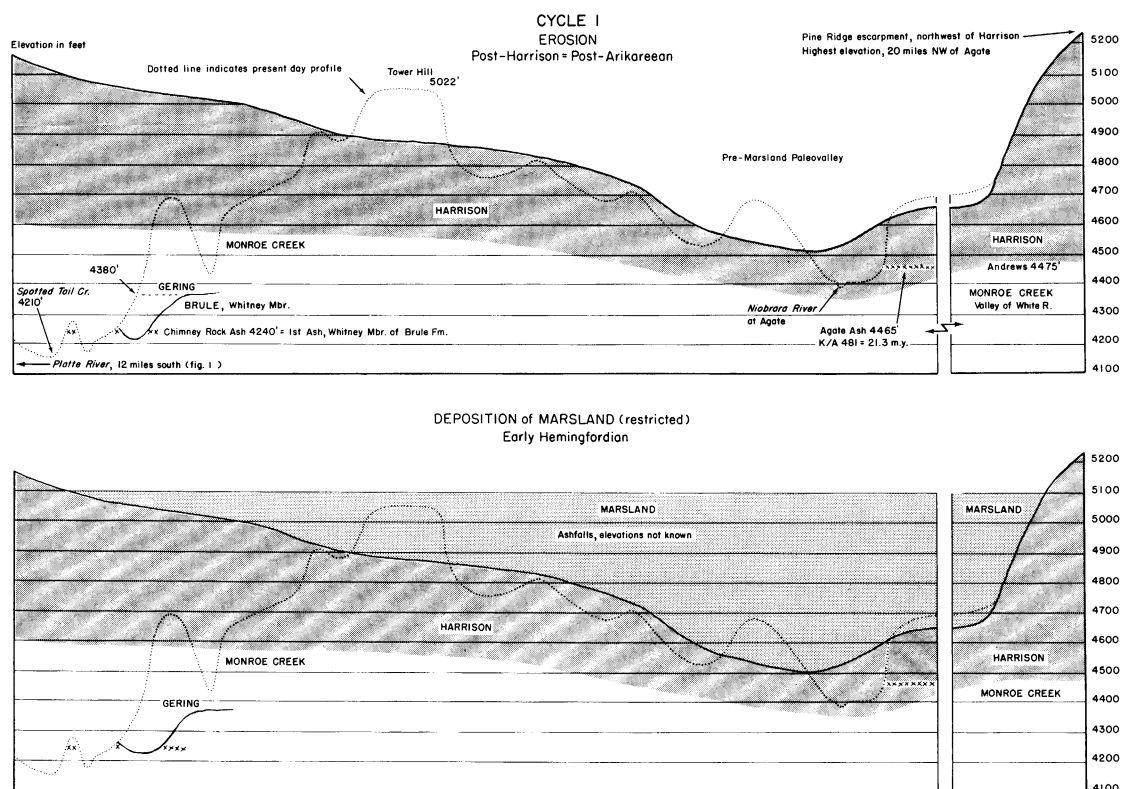


FIG. 8. Cycle 1: Diagrams of (1) post-Arikarean pre-Marsland valley; (2) Marsland deposition in Early Hemingfordian.

tion is unknown. Marsland sediments appear to have been mantling, in part at least, because no basal conglomerates have been observed. One volcanic ashfall at least, possibly more than one, is present in the Marsland (=Upper Harrison) in the area between Agate and Harrison. This ash was discovered by Ted Galusha and the senior author during a brief reconnaissance; no stratigraphic sections were made and there are no elevational controls as noted on figure 8. The separation between the Harrison Formation and the Marsland Formation (=Upper Harrison), or its temporal equivalent farther west toward the Hartville Uplift, requires more study because the lithologic distinction is not clear.

CYCLE 2 Figure 9

Medial to Late Medial Hemingfordian. Erosion. During Medial Hemingfordian time a

pre-Runningwater stream with a northeast trending drainage system cut through Marsland (=Upper Harrison) and Harrison sediments into the Monroe Creek Formation at the Runningwater type locality (Cook, 1965, figs. 1, 2). The valley of the drainage system into which Runningwater sediments were deposited, was almost as deep as the present Niobrara River drainage which it paralleled for some 70 miles (fig. 1A).

Deposition. Runningwater deposition occurred during Late Medial Hemingfordian. The most westerly known Runningwater outcrops occur along Nebraska Highway 29 (fig. 1A), and they crop out in the first valley south of the Niobrara River at Agate on the head of the Whistle Creek drainage that follows the general trend of the Runningwater paleovalley. The Runningwater Formation is well exposed at the type locality 19 miles east of Agate in the northwest corner of Box Butte County (Cook, 1965). From here an intermittent series of fossiliferous out-

crops are found eastward for another 50 miles, as far east as the west side of Cherry County, where Skinner (MS) developed a locality in 1938 known simply as "two miles west of Pole Creek."

Because the Runningwater sediments were deposited in an east-west trending valley, they are not nearly so widespread north and south. But wherever they are exposed in the Niobrara River drainage the pebbles and coarse sands of Rocky Mountain provenance and the gray sandstones cemented into hard ledges in outcrops are lithically distinct, not only from the Marsland Formation (=Upper Harrison), but also from all other sediments in which this ancient river system was entrenched. Several volcanic ashfalls are recognized in the filling phase, but have not been dated radiometrically. One distinctive ash in the Runningwater Formation type locality occurs at 4290 feet.

Although no radiometric dates are available for either the Marsland or Runningwater forma-

tions, they are bracketed by the Agate Ash of the Harrison Formation (21.3 m.y.), and by the Sheep Creek Ash (glass, K/A, 14.7 m.y.; fission-track date on zircon at 16.1 m.y.). A lengthy interval, therefore, of 6.6 m.y. can be estimated for (1) the remainder of Harrison deposition, (2) the development of the Harrison-pre-Marsland land surface and (3) deposition of the Marsland, (4) erosion and deposition in the Runningwater paleovalley, and (5) the erosion and deposition in the Sheep Creek paleovalley in Cycle 3. The pronounced faunal changes in this interval are explained partly by the passing of an estimated 6 million years.

CYCLE 3

Figure 10

Late Hemingfordian. During the early part of Late Hemingfordian in northwestern Nebraska the Sheep Creek and Box Butte drainage systems

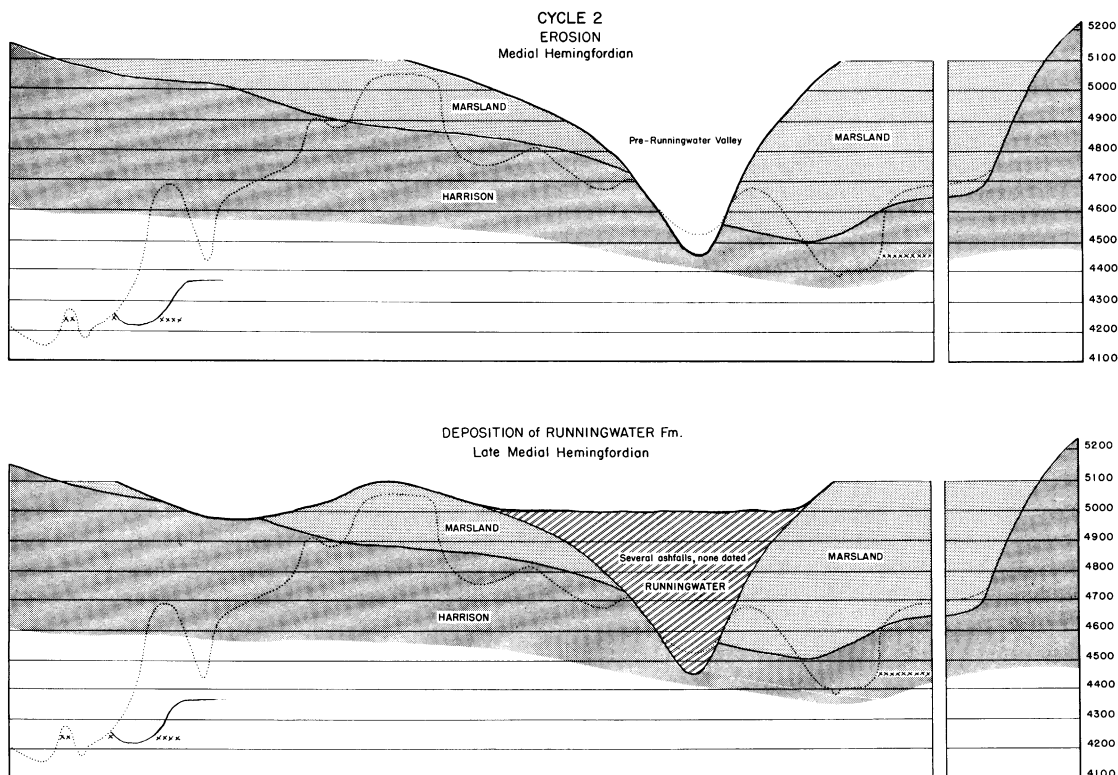


FIG. 9. Cycle 2: Diagrams of (1) Medial Hemingfordian pre-Runningwater valley; (2) deposition of the Runningwater Formation in Late Medial Hemingfordian.

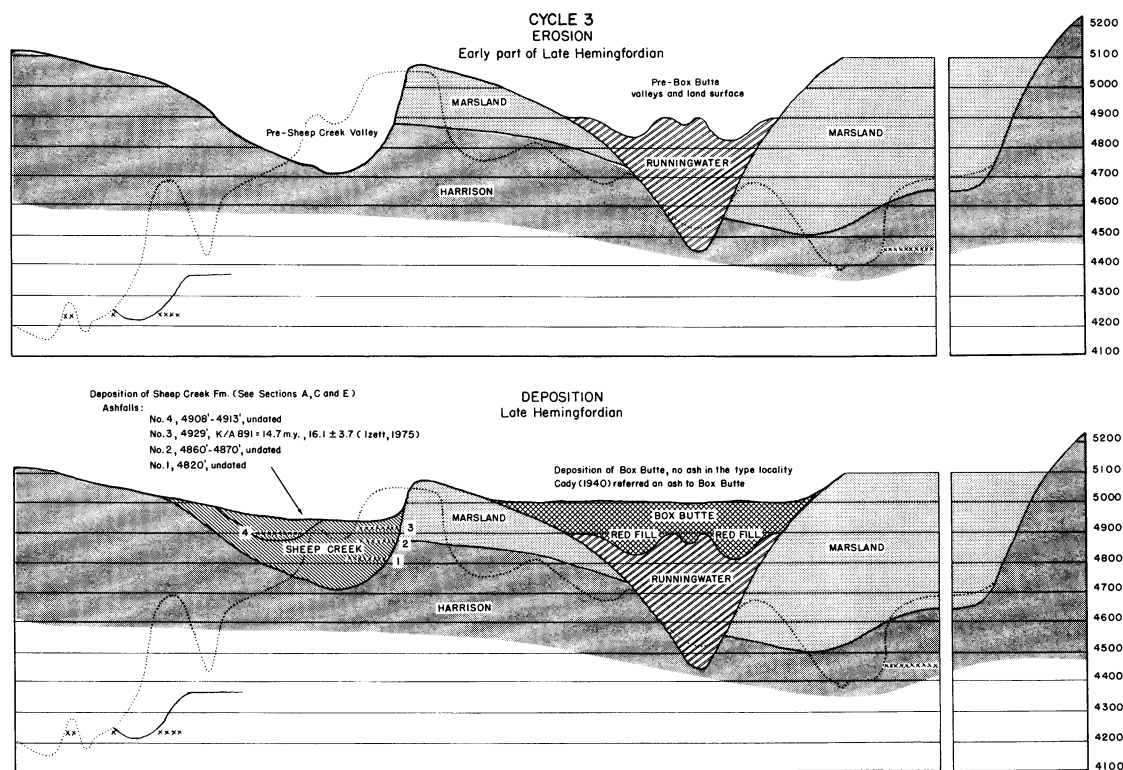


FIG. 10. Cycle 3: Diagrams of (1) pre-Box Butte; (2) pre-Sheep Creek land surfaces in early part of Late Hemingfordian; (3) deposition of Box Butte; (4) deposition of Sheep Creek Formation and volcanic ashes during Late Hemingfordian.

developed, but at different times and in different localities. Of these two drainages, Box Butte is the earliest. Although it is not in the study area, reference to it is included because the sediments were thought to be part of the Sheep Creek Formation by several authors (viz., A. L. Lugn, 1939; Cady, 1940; Wood et al. 1941; Elias, 1941, 1942; and Cady and Scherer, 1946). The latest and by far the most comprehensive study of the lithology, fossils, and published history of the Box Butte Formation is by Galusha (1975); see also present paper, p. 297, for discussion of the Box Butte.

Erosion of the Box Butte. Pre-Box Butte streams cut into Runningwater sediments and possibly into the Marsland Formation (=Upper Harrison), which are the only lithic units that the Box Butte Formation is known to overlie.

Deposition of the Box Butte. Channel fills (mainly clay, silt and sand) are found 30 to 35

miles northeast of the area occupied by the later Sheep Creek paleovalley and its fill.

Erosion of the Sheep Creek. In the early part of Late Hemingfordian time an east-trending valley about 3 miles wide was cut by a stream that eroded through the Marsland (=Upper Harrison) and into the Harrison Formation. The initial aggradation left a basal conglomerate of water-worn Harrison concretions southwest of South Snake Den Hill (fig. 6E). A remnant of the valley, which had a topographic relief of at least 250 feet, is preserved in the type area.

CYCLE 4

Figure 11

Late Hemingfordian and Early Barstovian. Erosion. Early Barstovian streams of Cycle 4 removed only a part of the Sheep Creek sediments in Ranch House and Antelope draws (fig.

2). In the vicinity of Olcott Hill and Sinclair draws, however, Sheep Creek, if it was ever present, has been completely removed, having left the Harrison surface exposed long enough to be subaerially weathered (fig. 5D).

Quarry operations in Antelope Draw uncovered several narrow, deep channel cuts with nearly vertical walls where ancient, rapidly flowing streams had cut trenches into and through Sheep Creek. The courses of some of these cuts (fig. 4A) show where their profiles crop out on the sides of recent draws (Echo and Mill quarries in Antelope Draw). Similar cuts are forming today in the valleys of the comparatively young post-Pleistocene Niobrara River and the still younger Snake River gorge in north-central Nebraska.

Early Barstovian erosion left considerable topographic relief for deposition of the Olcott Formation. In the final phase of degradation

remnants of the uplands and walls of the Olcott paleovalleys could have been composed of Harrison, Marsland (=Upper Harrison), or Sheep Creek.

Deposition. The known fills of Cycle 4 have no basal conglomerate such as those found at the base of the Sheep Creek (fig. 6E). The extent of aggradation and the thickness of the Olcott sediments during the later part of Cycle 4 can only be estimated, but the deposition needed to form valley walls and floors of the later Snake Creek paleovalleys is shown on figure 5D. At least 75 feet of Olcott sediments are preserved in the type outcrop on the northeast side of Olcott Hill.

Other drainage systems developed during Late Hemingfordian time in northwestern Nebraska, but their fills are not lithic continuations of the Sheep Creek. Each valley fill is a lithic unit within its own confines in space and time. Narrow, deep channel-trenches, such as those cut by

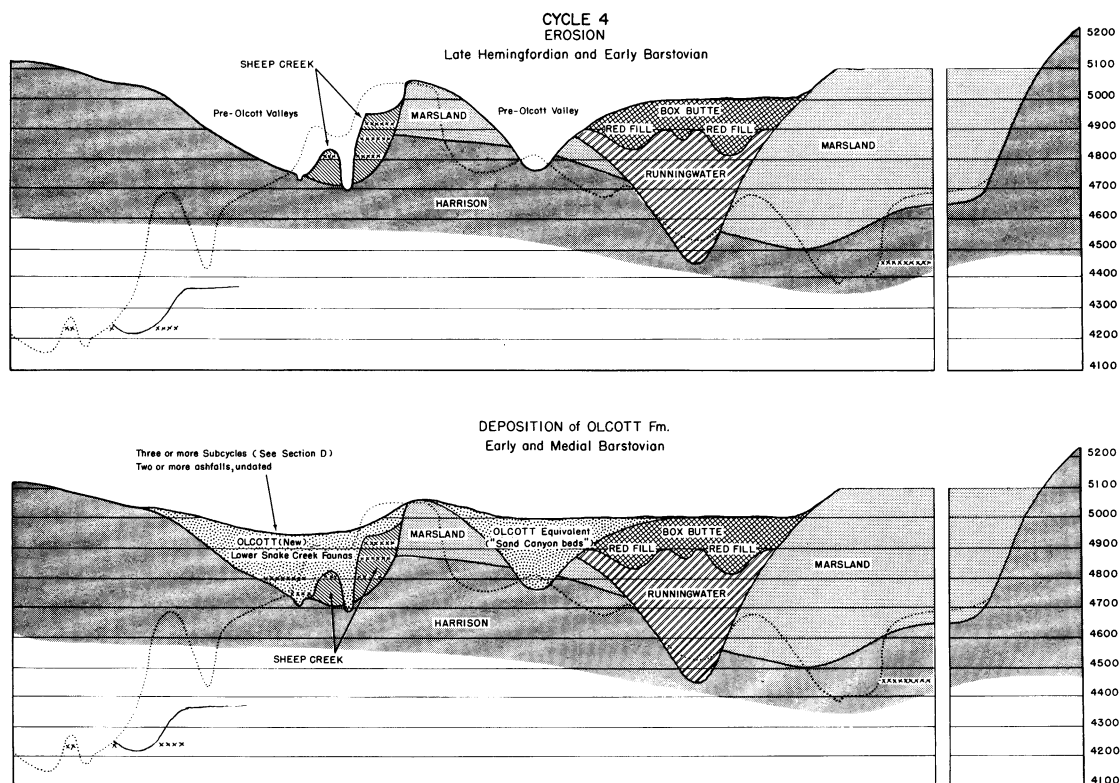


FIG. 11. Cycle 4: Diagrams of (1) pre-Olcott valleys during Late Hemingfordian and Early Barstovian time; (2) deposition of Olcott Formation during Early and Medial Barstovian.

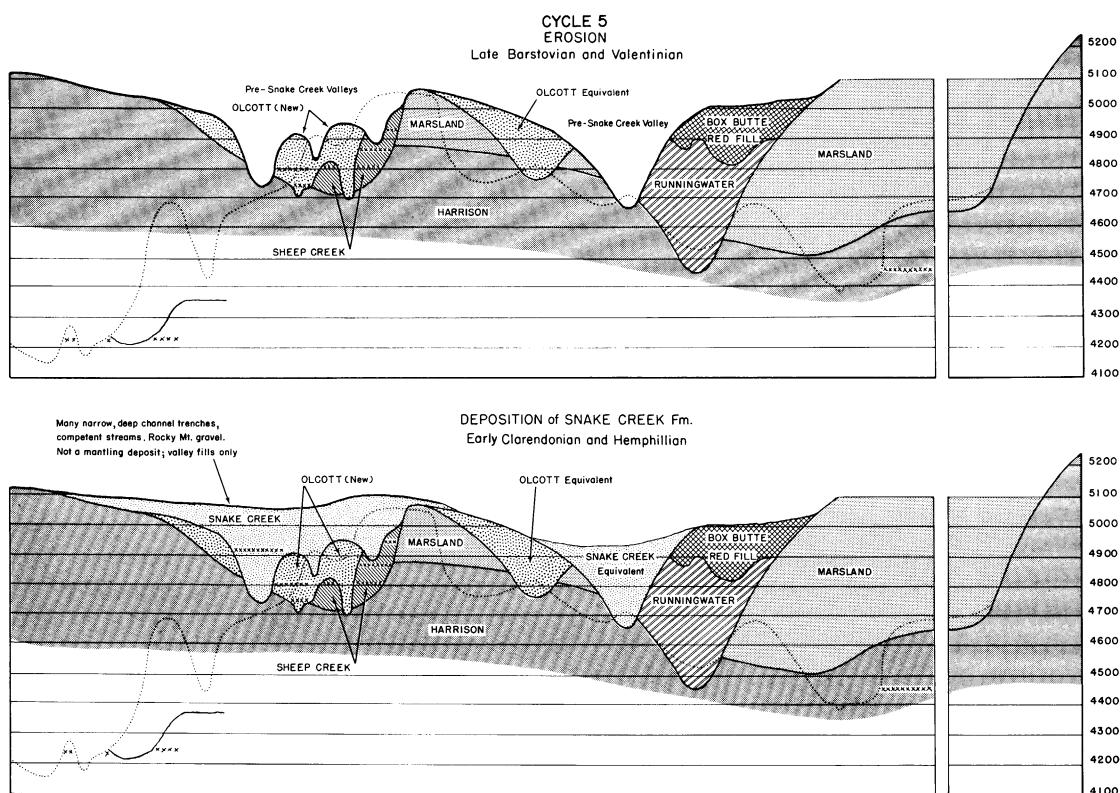


FIG. 12. Cycle 5: Diagrams showing (1) pre-Snake Creek valleys during Late Barstovian and Valentinian; (2) deposition of Snake Creek Formation during Early Clarendonian and Hemphillian times.

Olcott and Snake Creek degradation (figs. 11-12) have not been observed in the Sheep Creek degradation phase, suggesting that the Sheep Creek paleovalley was broader and more mature than these later systems.

Deposition of the Sheep Creek. Filling of the Sheep Creek paleovalley was not continuous, because two distinct minor erosion surfaces are present in the type area (figs. 4A-C). At least 195 feet of Sheep Creek sediments remain in the paleovalley, but an unknown amount may have been removed by erosion.

CYCLE 5 Figure 12

Late Barstovian, Valentinian, Clarendonian, and Hemphillian. The local sequence of rocks yielding Early and Late Clarendonian and Early

and Late Hemphillian fossils gives no hint of the events that took place from Late Barstovian through Valentinian time, because sediments of these ages are not found in the fill of Cycle 5. Moreover, local deposition during Clarendonian and Hemphillian time is preserved only as remnants, which makes it difficult to understand the paleogeomorphology; therefore, physical factors that resulted in these remnants can only be inferred.

Erosion. During the degradation of Cycle 5 vigorous streams developed extensive drainage systems. The elevations of these drainages and their sediments (ranging from 4835 to 4970 feet) can only mean that the valley walls had to be higher than their fills (figs. 5D, 6E). The elevations of deposits in Cycle 5 are well above the top of Scott's Bluff (4649 feet) in the Platte River Valley, and at Agate (4465 feet) in the

Niobrara River Valley (fig. 1B). These present-day drainages developed long after Late Hemphillian time.

Deposition. The earliest member of the revised Snake Creek Formation, Murphy Member (Early Clarendonian), was deposited on both Sheep Creek and Olcott surfaces. Sediments of the Murphy Member are so limited that little can be determined about their mode of deposition, and the relief, which developed after deposition, is only suggested at a few sites. After deposition of the Murphy Member, however, vigorous Snake Creek streams cut through the Murphy Member and into the underlying Sheep Creek. Remnants of sediments carried by these Snake Creek streams (Johnson Member) are scattered throughout the area and beyond it. Unconsolidated channel sand and coarser lag gravel filled deep, narrow channel-trenches in the bottoms of the valleys. Locally, these deposits are exposed on Olcott Hill, East *Pliohippus* Draw, and on the head of Dry Spotted Tail Creek.

Degradation apparently has continued in western Nebraska since Late Hemphillian time, the present topography being the result of the erosion phase of Cycle 6. This degradation phase is not the longest, but has produced more relief than any other since Early Arikareean time. Minor intervalley cuts and fills characteristic of the Pleistocene have not been observed in the study area, but such cuts are known in the Platte and Niobrara river valleys (i.e., Hay Springs, Broadwater, and the Ainsworth area).

In a diagrammatic summary, figure 13 explains the apparently anomalous occurrences on the divide between the Niobrara and Platte rivers, of various deposits superposed upon and eroded into each other. Most of the local deposits have now been named and the faunal accumulations have been allocated to specific rocks and a temporal framework. All of this can still be improved upon by the judicious use of radiometrical, paleomagnetic, and paleontological studies. In the early 1900s Matthew, Cook, and Sinclair had no access to the first two of these, and, indeed, work on the second has not yet begun, but they established a general picture of past life in the study area that has been modified only in a few details.

CYCLE 6
Figure 13

Late Hemphillian, Blancan, and Recent. Ero-

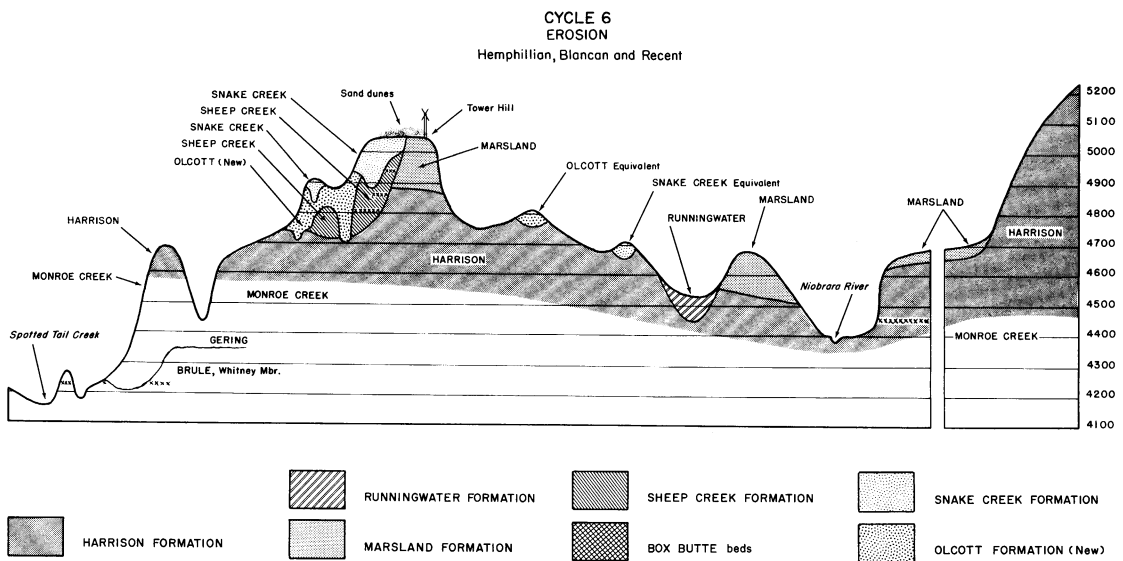


FIG. 13. Cycle 6: Profile showing relationship of Tertiary deposits in Hemphillian, Blancan, and Recent times.

QUARRIES OF THE SHEEP CREEK, OLCOTT, AND SNAKE CREEK FORMATIONS

INTRODUCTION

Figures 2, 3, 14-16

The geographic, geologic, and historic documentation for the quarries are now discussed. From 1941 to the present the senior author has systematically dealt with synonymous quarry names, giving each quarry the most suitable name, and assigning it as nearly as possible to its proper geographic and stratigraphic position within the various rock units. It is hoped that this will establish a sound foundation for biostratigraphic and temporal relationships for the rocks and faunas of this area.

Matthew (1924a, p. 63, fig. 1) explained the nomenclature of the draws: "The series of little draws in which the quarries are situated were named by our party for convenient reference, beginning at the west end . . . : West draw, *Aphelops* draw, *Merychippus* draw, West *Pliohippus* draw, East *Pliohippus* draw, Stonehouse draw, West and East Sinclair draw, Olcott hill." Wilson (MS) perpetuated Matthew's names and added the name "Sinclair Draw" to the western extension of West Sinclair Draw. Wilson also named Pigeon, Antelope, and Ranch House draws and our usage conforms with the names of Matthew and Wilson.

Aside from untangling and charting prior misinterpretations of the lithostratigraphy within the Sheep Creek-Snake Creek area, the greatest difficulty has been to ferret out the synonymous quarry and site names. Every available record has been studied in order to determine discovery dates and first and subsequent collectors. While the American Museum was collecting in the area, Osborn applied different numbers to quarries already numbered and named by Thomson, with the result that some have had as many names and numbers as the times they were worked.

Cook's collection,¹ which contains 50 pub-

lished types and several specimens that later may be designated as types, also posed a problem, for Cook's system of names for faunal sites had to be interpreted and synonymized along with the others. Much of the data associated with his specimens required a thorough knowledge of the area, but his catalogue of specimens and locality data provided valuable clues to the meaning of Matthew's, Sinclair's, Thomson's, and Whitford's concepts of the Sheep Creek-Snake Creek collections.

In 1932 Jack Wilson began collecting for the Frick Laboratory. He had no contacts with the American Museum or Princeton field men, or with Cook at Agate, and only later became aware of some of the previously assigned names and numbers, and thus numbered and zoned his collecting sites differently from collectors from other institutions. As Wilson's quarries yielded more fossils and became important sites, he applied distinctive names to them (e.g., Humbug, Echo, Trojan). Consequently, there came to be a plethora of names for each site (e.g., seven for East Surface Quarry), with the resultant confusion of data and the dissipation of single quarry faunas. From the beginning, however, Wilson kept his faunal sites in stratigraphic sequence; each suite of fossils can be identified with lithic units despite the various numbers and names.

The compilation of quarry names and discovery dates was immeasurably aided by Thomson's photographs and brief but concise notes, as well as the records of Sinclair and Whitford of the Princeton 1914 expedition, and Wilson's records from 1931 to 1940. Most of the American Museum 1908 and 1916 quarry sites and Sinclair's 1914 sites are shown on figures 2 and 15. Wilson's 1937 report to Frick, letters, maps, profiles, and photographs have been used extensively. In the course of this work Wilson's field list for 17,000 specimens in the Frick Collection were examined in order to eliminate synonymous quarry names. The chart (fig. 14) showing the sequence of rocks, local faunas, land mammal ages, and quarry sites from oldest to youngest, is the result of this work.

¹In 1963 Mrs. Harold J. Cook presented the Cook Collection to the Department of Vertebrate Paleontology, the American Museum of Natural History, New York. Morris F. Skinner, assisted by Robert J. Emry and Shirley M. Skinner, organized and packed the collection for shipment to New York from Agate, Nebraska.

Table 4 demonstrates the pitfalls of numbering and lettering quarries in a small area. In future studies Sheep Creek-Snake Creek specimens from numbered or lettered localities (whether

field listed, catalogued, or published) should have the collection date and source checked. Most of the data on the large collection of horses from this area have been corrected.

ROCK UNITS	FAUNAS	NORTH AMERICAN MAMMALIAN AGES	LOCAL GEOGRAPHY	ROCK SEQUENCE	STRATIGRAPHIC SECTIONS	QUARRIES For synonymous Quarry names see fig. 16 and index
SNAKE CREEK FORMATION	ZX Bar Local F.	Late HEMPHILLIAN	Northwest Part of Area	Johnson Member (New)	CF	Cook's <i>Pliohippus</i> Q.
	<i>Aphelops</i> Draw F.	Early HEMPHILLIAN			C	The Pits
	Snake Creek Fauna	Late CLARENDONIAN	Olcott Hill	Laucomer Member (New)	CE	<i>Aphelops</i> Qs. 1, 2 and 3
		Early CLARENDONIAN		Murphy Member (New)	D	Olcott Q. — Minor erosional hiatus —
OLCOTT FORMATION (new)	Lower Snake Creek Fauna	Early BARSTOVIAN	Olcott Hill, Ranch House, Antelope Draws	Relation to Subcycles unknown	D	<i>Hesperomithacus</i> Site
					A	Kilpatrick Q.
					D	Olcott Hill (and Slump Blocks, E. <i>Pliohippus</i> Draw)
					F	East <i>Pliohippus</i> Dr.
					B	Buck Q. (in part) — Major erosional hiatus —
					A	Boulder Q.
					A	Grass Roots Q.
					A	<i>Prosyntheloceras</i> Q.
					A	Mill, Floor of Mill Q.
					A	South Humbug Q.
					A	Humbug Q.
					A	Echo Q.
					D	New Sand Q.
					D	Verson Q.
					D	New Surface Q.
					D	Far Surface Q.
			Sinclair Draws	SUBCYCLE 3	D	West Surface Q.
					D	East Surface Q.
					D	<i>Mesoceras</i> Q.
					D	Princeton Loc. 1000 C (in part)
					D	AMNH 1908 Q.
					D	Pocket 34 — Minor erosional hiatus —
					D	West Jenkins Q.
					D	East Jenkins Q.
				SUBCYCLE 2	D	Jenkins Q.
					D	Sand Q.
					D	West Sand Q.
					D	East Sand Q.
					D	Sinclair Q.
					D	Princeton Loc. 1000 C (in part) — Minor erosional hiatus —
					D	Douglas Q.
					D	East Wall Q.
				SUBCYCLE 1	D	North Wall Q.
					D	Trojan Q.
					D	Snake Q.
					D	Camel Q.
SHEEP CREEK FORMATION	Sheep Creek Fauna	Late HEMINGFORDIAN	North and West of Sinclair Draws	Upper Part		No fauna — Major erosional hiatus —
				Middle Part	A	Above Greenside Q. — Minor erosional hiatus —
					A	Above Long Q.
					—	Conference Q.
					B	Buck Q. (in part)
					C	Target Q.
					E	Ashbrook Q.
					C	Vista Q.
					C	Rhino Q.
					A	East Ravine Q.
					A	Ravine Q.
					A	Thistle Q.
					A	East Hilltop Q.
					A	Hilltop Q.
					BC	North Thomson Q.
					BC	Thomson Q.
				Lower Part	A	Long Q. — Minor erosional hiatus —
					A	Greenside Q.

FIG. 14. Correlation chart showing faunas, mammalian ages, local geography and rock sequence. The list of quarries indicates occurrence within a specific stratigraphic unit but does not show superposition within that unit.

TABLE 4
Examples of Confusion in Numbered Quarry Sites

Author or Collector	Year	Quarry Number	Source of Data	Location as First Cited	Present Identification
Matthew, Cook, Thomson	1908	1	Thomson's (MS.a) for AMNH 13885	20 mi. S of Agate, Snake Creek beds	Suspect Olcott Hill by elimination, photographs (AMNH 18358, 18360) and Thomson's letter (August 18, 1918)
Matthew, Cook, Thomson	1908	2	Thomson's (MS.a) for AMNH 14070	20 mi. S of Agate, Snake Creek beds	Probably East Sinclair Draw. See photograph (AMNH 18359), Matthew and Cook (1909, p. 402), Matthew (1924a, p. 186) for type of <i>Aepyamelus procerus</i> . Also present paper, p. 348
Matthew, Cook, Thomson	1908	3	Thomson's (MS.a) for AMNH 14071	20 mi. S of Agate, Snake Creek beds	East <i>Pliohippus</i> Draw. See Matthew and Cook (1909, p. 396) for <i>Megatylopus gigas</i> , and present paper, p. 360
Thomson	1918	1	Thomson (MS.b) and map (fig. 16)	Snake Creek beds, head of <i>Aphelops</i> Draw	Thomson's map (fig. 16) showed 1918 quarries 1, 2, 3, around head of <i>Aphelops</i> Draw
Thomson	1918	2	Thomson's map (fig. 16)	South of 1918 Quarry 1	No specimens from Quarry 2 in Thomson's (MS.b) field list
Thomson	1918	3	Thomson's map (fig. 16)	Northwest of 1918 Quarry 1	No specimens from Quarry 2 in Thomson's (MS.b) field list
Osborn	1936	1	Map and table, pp. 426-427	<i>Aphelops</i> Draw, included Thomson's 1918 Qs. 1, 2, 3	Map (fig. 392) gave longitude, latitude, sections, townships, ranges, county, state in legend for diagrammatic sections (fig. 393), but north-south sections is 1½ mi. too far east
Osborn	1936	2	Map and table, pp. 426-427	Sinclair Draw	Three quarries shown in East Sinclair Draw. See present paper, fig. 15
Osborn	1936	3	Map and table, pp. 426-427	Olcott Hill	Included many names and sites (present paper, fig. 15)
Osborn	1936	4	Map and table, pp. 426-427	<i>Pliohippus</i> Draw	Cook's <i>Pliohippus</i> Quarry (present paper, fig. 7F)
Osborn	1936	5	Map and table, pp. 426-427	The Pits	The same as Thomson's 1923-1925 "The Pits"
Osborn	1936	6	Map and table, pp. 426-427	North of Olcott Hill	The same as Thomson's 1925 "Grass Roots Q"
Osborn	1936	7	Map and table, pp. 426-427	Northwest part of Olcott Hill	The same as Thomson's 1925 "Kilpatrick Q"
Wilson	1932	1-5	Map and table, pp. 1932 (MS)	East Sinclair Draw	The same as Osborn's (1936, fig. 392) Quarry 2 (present paper, fig. 15)
Wilson	1932	6-9	1932 (MS)	West Sinclair Draw	Present paper (fig. 15)

QUARRIES IN THE SHEEP CREEK FORMATION

EARLY MIOCENE (LATE HEMINGFORDIAN)

LOWER PART OF SHEEP CREEK FORMATION

Greenside Quarry. Situated in a branch of Ranch House Draw, in the northeast corner of the NE $\frac{1}{4}$, NE $\frac{1}{4}$, sect. 4, so near the section line that it can also be described as in the northwest corner of sect. 3, T. 25 N, R. 55 W, Sioux County, Nebraska. Elevations from 4814 to 4829 feet. Figures 2, 4A, 14.

Synonyms. None.

Repository of Fossils. Frick Collection.

History. Discovered by Wilson in June, 1935, and worked by him through the 1930s. Worked by Skinner in the 1940s.

Remarks. The fossil-producing matrix, which is near the Harrison contact with Sheep Creek, is overlain by a massive, fine, pink to brown sand similar to outcrops just north of Ashbrook Quarry in the lower part of the Sheep Creek Formation near Snake Den Hills (figs. 2, 6E). Similar sediments are exposed on the south side of Antelope Draw, south of Echo Quarry and in Stonehouse Draw north of Thomson Quarry.

The superposition of the Olcott Formation on the Sheep Creek can be seen at Greenside Quarry where the *Prosynthetoceras* Quarry (Olcott Formation) overlies Greenside Quarry sediments in unconformable erosional contact (fig. 4A). The present drainage cuts across *Prosynthetoceras* Quarry creating the possibility of a mixed fauna in float material.

Greenside Quarry is nearly equal in age to Long Quarry, $\frac{1}{4}$ mile north (figs. 2, 4A).

Long Quarry. Situated on the north side of Antelope Draw in the head of a small side wash near the middle of the west line of the SW $\frac{1}{4}$, NW $\frac{1}{4}$, SW $\frac{1}{4}$, sect. 34, T. 26 N, R. 55 W, Sioux County, Nebraska. Elevation, 4794 feet. Figures 2, 4A, 14.

Synonym. Wilson (MS, 1933), "Sheep Creek Channel Bed, Antelope Draw."

Repository of Fossils. Frick Collection.

History. Discovered by Wilson July, 1934, named for Carl Long, a Frick collector. With the exception of the first 48 specimens (field nos.

967-1016 and 1528-1519), fossils from here were listed by Wilson as having been collected from Long Quarry.

Remarks. Fossil-producing matrix was deposited within the massive, pinkish deposits of the lower part of the Sheep Creek Formation. Quarry outcrops are in a small draw and show a direct superposition of deposits (see Above Long Quarry, p. 328). The elevation of Long Quarry is the lowest of the Sheep Creek quarries and might be expected to have the oldest faunal assemblage, but the horses from Greenside and Long quarries are similar and indicate that the two quarries were nearly contemporaneous. Wilson's (MS, 1934) preliminary concept and sketch of Long Quarry indicate that he did not realize that the Olcott Formation is also present in Antelope Draw, but in September of the same year he reported that the Echo Quarry channel (Olcott Formation) had cut through Long Quarry deposits.

MIDDLE PART OF SHEEP CREEK FORMATION

Thomson Quarry. Situated on the east side of Stonehouse Draw, about one-fourth mile below its head in the western part of the SW $\frac{1}{4}$, SW $\frac{1}{4}$, sect. 33, T. 26 N, R. 55 W, Sioux County, Nebraska. Excavations extend for about 670 feet. Elevation at floor 4829 feet. Figures 2, 4B, C, 6E, 7F, 14.

Synonyms. Thomson (MS.e, 1922 and MS.f, 1923): "Sheep Creek Quarries." Wilson (MS 1933): Thomson Quarry.

Repository of Fossils. Department of Vertebrate Paleontology, Frick Collection; Cook Collection, the American Museum of Natural History. Most of the specimens are in the Frick Collection. A few may be in other institutions.

History. Thomson (MS.e, 1922) stated: "we began working a Sheep Creek Channel bed in the same pasture (Kilpatrick pasture) . . ." Thomson (MS.f, 1923) noted that on "June 15th we began work in the Snake and Sheep Creek quarries where we left off in 1922." Matthew (1924a, p. 64, fig. 1) showed the site as "Sheep Creek

Quarry, Exp. 22-23," remarking that "in 1922-23, some collecting was done in *Aphelops* and *Pliohippus* draws, but the principal collection made is from a channel-bed in Stonehouse Draw containing the *Merychippus primus* fauna."

Wilson reopened the site in June, 1933, and named it "Thomson Quarry" after Albert Thomson. It will be noted that Cook applied the name "Thomson Quarry" to Thomson's "Sheep Creek Channel Bed" in East Sinclair Draw, here known as Trojan Quarry in the Olcott Formation (p. 329). Wilson collected from Thomson Quarry in the 1930s and Skinner in the 1940s.

Remarks. Thomson Quarry is in the base of the middle part of the Sheep Creek Formation that rests disconformably on the lower part. It is stratigraphically higher than Long and Greenside quarries, equivalent to Hilltop, East Hilltop, Ravine and East Ravine, Thistle, and Vista quarries, and isolated prospecting sites in the study area.

The Sheep Creek Formation is exposed on the east side of Stonehouse Draw, but deposits of other ages are also found along the draw at the same elevation. Directly west of Thomson Quarry across Stonehouse Draw, a Snake Creek channel-cut has removed Sheep Creek sediments, cutting deeper than the fossil-producing level of Thomson Quarry. The stream that cut this Snake Creek channel and left deposits, apparently had a northwesterly-southeasterly trend. Toward the head of Stonehouse Draw to the north and less than a quarter-mile away, another Sheep Creek fluvial deposit (an ashy sand) that contains Target Quarry (figs. 2, 4B), is exposed just below the sod cover. A fluvial fill of unconsolidated well-sorted sand (Olcott Formation) cuts across Stonehouse Draw between Thomson and Target quarries (fig. 4B) but specimens from this deposit are too few and fragmentary for identification.

Matthew (1924a, p. 71) included the fossils from Thomson Quarry in his *Merychippus primus* zone that he considered as the "lower part of the Sheep Creek" Formation (fig. 4B, C) because he knew nothing of the stratigraphically lower Long and Greenside quarries discovered by Wilson in 1934 and 1935.

North Thomson Quarry. Situated on the west

side of Stonehouse Draw in the NW $\frac{1}{4}$, NW $\frac{1}{4}$, SW $\frac{1}{4}$, SW $\frac{1}{4}$, sect. 33, T. 26 N, R. 55 W, Sioux County, Nebraska. North Thomson is a northern extension of Thomson Quarry that was worked only by the Skinner party in the 1940s. The fossils were listed separately in case of a lateral change in sedimentation.

Hilltop Quarry. Situated on top of a small ridge just south of Antelope Draw in the northwest corner of the NE $\frac{1}{4}$, SW $\frac{1}{4}$, SW $\frac{1}{4}$, sect. 34, T. 26 N, R. 55 W, Sioux County, Nebraska. Elevation of sod near Hilltop Quarry above the fossil zone, 4809 feet. Figures 2, 4A.

Synonyms. None.

Repository of Fossils. Frick Collection.

History. Discovered by Wilson and Long in October, 1934.

Remarks. Stratigraphically, Hilltop Quarry is in the base of the middle part of the Sheep Creek Formation, and disconformably overlies either the lower part of the Sheep Creek Formation or a Harrison remnant. The fossil-producing matrix is a fluvialite deposit composed primarily of reworked Sheep Creek rocks. The fossils are similar to those from other quarries that form the Thomson Quarry faunal zone at the base of the middle part of the Sheep Creek Formation. Hilltop is stratigraphically equivalent to Thomson, the Ravine, East Hilltop, Thistle, Vista, Above Long, and Above Greenside quarries.

East Hilltop Quarry. Situated south of Antelope Draw, about 100 yards east of Hilltop Quarry near the northeast corner of the NE $\frac{1}{4}$, SW $\frac{1}{4}$, SW $\frac{1}{4}$, sect. 34, T. 26 N, R. 55 W, Sioux County, Nebraska. Elevation of sod above fossil zone is the same as for Hilltop, 4809 feet. Figures 2, 4A.

Synonyms. None.

Repository of Fossils. Frick Collection.

History. Discovered by Skinner in 1946.

Remarks. East Hilltop Quarry is an eastward extension of the Hilltop Quarry fossil-producing matrix. No connection was made between the two fossil sites, however, and the specimens have been kept separate.

Thistle Quarry. Situated on a short, southwest trending branch of Antelope Draw, in the eastern

part of the NE $\frac{1}{4}$, SE $\frac{1}{4}$, SE $\frac{1}{4}$, sect. 33, T. 26 N, R. 55 W. Elevation near quarry 4821 feet. Figures 2, 4A.

Synonyms. None.

Repository of Fossils. Frick Collection.

History. Discovered by Wilson and Long in October, 1935. Worked by Wilson in the 1930s and by Skinner in the 1940s.

Remarks. Sediments that make up the fossil-producing matrix are similar to those of Thomson, the Hilltop, Ravine, and Vista quarries. Stratigraphically, Thistle Quarry is near the base of the middle part of the Sheep Creek Formation, above the local disconformity between the lower and middle parts of the formation.

Ravine Quarry. Situated in the extreme head of the northwest trending branch of Ranch House Draw southwest of Hilltop Quarry, in the northwest corner of the SW $\frac{1}{4}$, SW $\frac{1}{4}$, SW $\frac{1}{4}$, sect. 34, T. 26 N, R. 55 W, Sioux County, Nebraska. Elevation of sod above quarry on south side 4821 feet. Figures 2, 4A.

Synonyms. None.

Repository of Fossils. Frick Collection.

History. Discovered by Wilson July 19, 1937 and worked by him in the 1930s. Worked by Skinner and parties in the 1940s.

Remarks. Ravine and East Ravine quarries were refilled by Wilson in compliance with an agreement with the Kilpatrick ranch owners. Skinner uncovered a part of the old working face of the quarries in order to determine the type and thickness (5 to 12 feet) of the fauna-producing matrix.

East Ravine Quarry. Situated in a west-trending branch of Ranch House Draw near the northwest corner of the NW $\frac{1}{4}$, NW $\frac{1}{4}$, NW $\frac{1}{4}$, sect. 3, T. 25 N, R. 55 W, Sioux County, Nebraska. Elevation of sod near quarry 4822 feet. Figures 2, 4A.

Synonyms. None.

Repository of Fossils. Frick Collection.

History. The first fossils were sent in by Wilson in August, 1939, and very little collecting was done before the quarry was filled in. Skinner made no collections here.

West Ravine and New Ravine Quarries. These

names appear on a drainage map made by Skinner in 1942, but apparently neither name was used for a quarry. When Skinner was shown the quarry sites by Arnold Martin and Richard Jenkins (members of Wilson's party), these two names may have been used for prospecting sites that were unfossiliferous.

Rhino Quarry. Situated on the north side of East *Pliohippus* Draw on a south-facing bank of the ridge, near the center of the east line of the SW $\frac{1}{4}$, NW $\frac{1}{4}$, sect. 32, T. 26 N, R. 55 W, Sioux County, Nebraska. Elevation 4875 feet. Figures 2, 4C.

Synonyms. None.

Repository of Fossils. Frick Collection.

History. Discovered by Wilson and party in late summer of 1937.

Remarks. Sediments of the fossil-producing matrix are about 10 feet of well-consolidated, massive, whitish sandy clay.

Vista Quarry. Situated on the south side of a high hill in the southwest corner of the SE $\frac{1}{4}$, NW $\frac{1}{4}$, NE $\frac{1}{4}$, sect. 5, T. 25 N, R. 55 W, Sioux County, Nebraska. Vista Quarry is in some of the most southern exposures of the area and overlooks the North Platte Valley to the south. Elevation of the top of the Harrison Formation below Vista Quarry 4828 feet; floor of quarry 4845 feet. Figures 2, 4C.

Synonyms. None.

Repository of Fossils. Frick Collection.

History. Discovered by Skinner and party in September, 1945.

Remarks. The fossil-producing matrix is typical of the Thomson Quarry lithic zone and is stratigraphically equivalent to Thomson, the Hilltop and Ravine quarries, and Above Long and Above Greenside quarries. Vista Quarry is near the base of the middle part of the Sheep Creek Formation and disconformably overlies the lower part of the Sheep Creek.

Ashbrook Quarry. On the north face of a butte in the southernmost remnant of the Sheep Creek Formation in the western part of the area, near the southwest corner of the NE $\frac{1}{4}$, SE $\frac{1}{4}$, SE $\frac{1}{4}$, sect. 31, T. 26 N, R. 55 W, Sioux County, Nebraska. Elevation 4842 feet. Figures 2, 6E.

Synonyms. None.

Repository of Fossils. Frick Collection.

History. Discovered by Wilson June, 1937, and worked by him in the late 1930s, and by Skinner in the 1940s.

Remarks. The fossil-producing matrix is a fluvial, consolidated, sandy clay that weathers nearly white, in sharp contrast to sediments of other quarries near the base of the middle part of the Sheep Creek Formation (i.e., Thomson and Vista quarries). North of the quarry, at least 60 feet of erosional relief can be observed on the contact between the Harrison and Sheep Creek formations. This relief seems to indicate that Ashbrook Quarry lies along the south side of the Sheep Creek paleovalley.

Target Quarry. Situated near the head of Stonehouse Draw, about one-third mile above Thomson Quarry in the NE $\frac{1}{4}$, NE $\frac{1}{4}$, SE $\frac{1}{4}$, sect. 32, T. 26 N, R. 55 W, Sioux County, Nebraska. Elevation at floor of quarry 4861 feet. Figures 2, 14. See also figures 4B and 4C for stratigraphic position and figures 6E and 7F for relative positions by elevations.

Synonyms. None.

Repository of Fossils. Frick Collection.

History. Discovered by Skinner and party in August, 1947, after a torrential rain had washed out a gully at the extreme head of Stonehouse Draw and exposed the fossil concentration.

Remarks. Target Quarry is 29 feet above the Thomson Quarry lithic zone but still is in the middle part of the Sheep Creek Formation. Only small outcrops are exposed at the gully. The thin (2 or 3 feet thick) fossil-producing zone is a massive, grayish buff, dusty, ashy sand that disconformably overlies deposits that in turn overlie the fossil-producing zone of Thomson Quarry. Target Quarry is overlain by a Recent fill that contains gravel reworked from the Snake Creek Formation.

The lithology of the fossil-producing matrix is unlike that of any other deposit in the area. Target Quarry is richly fossiliferous, with a proportionally large number of articulated specimens. These fossils, unfortunately, do not absorb shellac well and are difficult to harden, probably because of the fine, silty nature of the matrix.

Buck Quarry. Situated at the head of the east

branch of Stonehouse Draw near the northeast corner of the NE $\frac{1}{4}$, SE $\frac{1}{4}$, NW $\frac{1}{4}$, sect. 4, T. 25 N, R. 55 W, Sioux County, Nebraska. The Harrison Formation is exposed in the bottom of the wash at 4790 feet; Sheep Creek Formation at 4823 feet; Olcott Formation at 4827 feet; Snake Creek Formation, bottom of fluvial cut at 4803 feet. Figures 2, 4B, C.

Synonyms. None.

Repository of Fossils. Frick Collection.

History. Discovered by Skinner and party, 1941. Small collections made in 1941 and 1942.

Remarks. Two channel deposits intersect at Buck Quarry: (1) A semiconsolidated channel of local Sheep Creek type sediments that contains fossils of Sheep Creek age, and (2) a much younger Snake Creek channel that is incised into the Sheep Creek channel. The Snake Creek channel, which was exposed during quarry excavation, has unconsolidated, well-sorted, medium coarse quartz sand. Care was taken to give the zone of each specimen as it was collected.

Conference Quarry. Situated on the east side of Nebraska State Highway 29 (as of 1973), $1\frac{1}{4}$ miles south of the Vance Johnson turn-off, on the south side of the SW $\frac{1}{4}$, NE $\frac{1}{4}$, NE $\frac{1}{4}$, sect. 36, T. 26 N, R. 56 W, Sioux County, Nebraska. Elevation not taken; no section made; Conference Quarry is not on the map (fig. 2) but an arrow points toward the location which is outside the mapped area (fig. 2).

Synonyms. None.

Repository of Fossils. Frick Collection.

History. Discovered August, 1967, following a conference with the University of Nebraska and other institutions, on the Miocene formations in western Nebraska. The American Museum party parked automobiles at this site while reconnoitering the northwest part of the Sheep Creek-Snake Creek area. Fossils were found at this roadcut.

Above Long Quarry. Directly overlies Long Quarry on the north side of Antelope Draw on the head of a small side wash near the middle of the west side of the SW $\frac{1}{4}$, NW $\frac{1}{4}$, SW $\frac{1}{4}$, sect. 34, T. 26 N, R. 55 W, Sioux County, Nebraska. Elevation at contact with Long Quarry 4814 feet. Figures 2, 4A, 14.

Synonyms. "Over Long Quarry."

Repository of Fossils. Frick Collection.

History. Discovered by Wilson and party in June or July, 1934. First shipment of fossils was made on August 15, 1934. Small collections were made by Wilson in the 1930s and by Skinner in the 1940s.

Remarks. Above Long Quarry is in the base of the Thomson Quarry lithic zone as it rests disconformably on the older Sheep Creek deposits that contain the Long Quarry fossils.

Above Greenside Quarry. Situated 9 feet above the top of the fossil-producing matrix of

Greenside Quarry. Elevation 4838 feet. Figures 2, 4A, 14.

Synonyms. "Over Greenside Quarry."

History. Discovered by Wilson in 1935. Nine specimens were sent in Sioux County Box 203 on September 11, 1935. This quarry was never worked by Skinner.

Remarks. Above Greenside is a small quarry in a 4 or 5 foot layer of massive, fine, pink or brown unconsolidated sand and silt that resembles the fossil-producing matrix of Above Long Quarry.

QUARRIES IN THE OLCOTT FORMATION

MEDIAL MIOCENE (EARLY BARSTOVIAN)

QUARRIES OF SUBCYCLE 1

Camel Quarry. Situated on the east side of East Sinclair Draw on the west-central side of the SW $\frac{1}{4}$, NW $\frac{1}{4}$, NE $\frac{1}{4}$, NW $\frac{1}{4}$, NE $\frac{1}{4}$, sect. 10, T. 25 N, R. 55 W, Sioux County, Nebraska, directly below, and covered by the overburden of Far Surface Quarry. Elevation at floor 4835 feet. Figures 5D, 14, 15.

Synonyms. Thomson (MS.d, 1921): "Quarry B" (in part). Matthew (1924a, fig. 1): "Quarry 21" (in part). Wilson (MS, 1932): "Sinclair Q. No. 5, Hor. B." Wilson (MS, 1937): "Camel Q. No. 5." Skinner (MS, 1941): Camel Quarry.

Repository of Fossils. Department of Vertebrate Paleontology and the Frick Collection, the American Museum of Natural History.

History. Whitford in 1916 gave no name, but we suspect that he may have worked Camel Quarry.

Remarks. The matrix is mostly sand and ash with an overall gray appearance; channel indications are at the base. The quarries of Subcycle 1 are in the oldest of the Olcott sediments that directly overlie the Harrison Formation in this area. The temporal equivalents of Camel Quarry are Snake, Trojan, North Wall, East Wall, and Douglas quarries.

Snake Quarry. Situated at the head of East Sinclair Draw on a south-facing outcrop in the western part of the NE $\frac{1}{4}$, NE $\frac{1}{4}$, NW $\frac{1}{4}$, NW $\frac{1}{4}$, NE $\frac{1}{4}$, sect. 10, T. 25 N, R. 55 W, Sioux County,

Nebraska. Elevation at floor 4835 feet. Figures 5D, 14, 15.

Synonyms. Wilson (MS, 1932): "Sinclair Q. No. 1, Hor. B." Wilson (MS, 1937): "Snake Q. No. 1." Skinner (MS, 1941): Snake Quarry.

Repository of Fossils. Frick Collection.

History. Discovered by Wilson in August, 1932, and worked by him in 1932, 1933, 1937, and by Skinner in the 1940s.

Remarks. Snake Quarry is in the basal part of the Olcott Formation in this area. The fossil-producing matrix is near the base of the sandy ash that overlies the Harrison Formation in erosional contact.

Trojan Quarry. Situated on the east side of East Sinclair Draw south of all other quarries in this small area, in the eastern half of the NW $\frac{1}{4}$, SW $\frac{1}{4}$, NE $\frac{1}{4}$, NW $\frac{1}{4}$, NE $\frac{1}{4}$, sect. 10, T. 25 N, R. 55 W, Sioux County, Nebraska. Elevation at floor of quarry 4822 feet; top of quarry 4845 feet. Figures 5D, 14, 15.

Synonyms. Thomson (MS.d, 1921): "Chan. Bed Sheep Cr. Q. 21." Matthew (1924a, fig. 1): "Quarry 21" (in part). Wilson (MS, 1932): "Sinclair Q. No. 4, Hor. A." Osborn (1936, fig. 392): "Quarry 2" (in part). Wilson (MS, 1937): "Trojan Q. No. 4." Skinner (MS, 1941): "Trojan Quarry."

From 1916 through 1957 Cook collected specimens from Trojan Quarry, but used various ways of describing the site. Cook may not have known that Thomson's name for the site was the "Sheep Creek Quarry." Cook (MS) gave the fol-

lowing terms for this quarry, as well as clues to the evolution of his usage for East Sinclair Draw, "Thomson Quarry," and "East Quarry" or pocket, as indicated in the following examples:

HC 465 (=AMNH 8362), 1922: "Snake Creek beds, Channel Bed 100 yds. west [but should be east] of 'Sinclair Draw' which was found by A. Thomson & opened summer of 1921, by the Am. Mus. of Nat. Hist. party, in lowest phase of Snake Creek beds, cut down into the Snake Creek Beds [Harrison Formation]."

HC 467, 1921: "Thomson Quarry—lowest Snake Creek beds—just east of 'Sinclair Draw.'"

HC 473 (=AMNH 8348), 1933: "Lower Snake Creek Beds. Sinclair Draw, East Pocket; (*Alligator Thomsoni* Quarry)." These data verified the source of *A. thomsoni* type that Mook (1923) neglected to give in his original citation.

HC 875 (=AMNH 6610), 1954: "Sinclair Draw—East Quarry. Snake Creek Beds. Lower Pliocene."

HC 917 (=AMNH 81077), 1957: "East Pocket, East Sinclair Draw. Snake Creek Beds."

HC 995 (=AMNH 85815), 1916: Same data as for HC 875 (=AMNH 6610). Collecting data of "June 14, 1916" was the year that Whitford and Stoll collected for the American Museum, and shows that Trojan Quarry was known prior to Thomson's 1921 opening.

Repository of Fossils. Department of Vertebrate Paleontology; Frick and Cook collections, the American Museum of Natural History.

History. The synonyms for Trojan Quarry have tended to dissipate the fauna more than any other quarry in the area. Thomson's (MS.d) name "Sheep Creek Quarry" was misleading then and has remained so. Thomson did not mean that Sheep Creek fossils came from the quarry when he stated: "A fifth quarry which was about 10 feet lower than Quarry A and B we called the Sheep Creek Quarry because it is in a channel bed cut down into the Sheep Creek beds [here considered the Harrison Formation]. Though the material obtained in it seems to be the same as in Quarry A and B."

Remarks. Trojan Quarry is in the basal part of Subcycle 1 and rests disconformably on the Harrison Formation. The fossil-bearing matrix is a mixture of sand and volcanic ash. Most of the fossils were found near the base of the deposit.

North Wall Quarry. Situated at the head of

West Sinclair Draw on the east side of the wash in the south-central part of the SW $\frac{1}{4}$, SW $\frac{1}{4}$, SE $\frac{1}{4}$, sect. 3, T. 25 N, R. 55 W, Sioux County, Nebraska. Elevation at bottom of channel 4830 feet; top of channel 4840 feet. Figures 5D, 14, 15.

Synonyms. Sinclair (1915): "Princeton's 1914 Locality 1000C" (in part). Wilson (MS, 1932): "Sinclair Draw, Q. No. 7, Hor. A." Wilson (MS, 1937): "North Wall Q., No. 7." Skinner (MS, 1941): North Wall Quarry.

Repository of Fossils. Princeton University; Frick Collection.

History. The Princeton party (Sinclair, Whitford, Barner) worked near North Wall Quarry as did Whitford and Stoll in 1916. The main quarry concentration, however, was worked by Wilson in 1932, 1933, and 1935 to 1937.

Remarks. North Wall is about 75 feet across the head of the draw from Wilson's West Surface Quarry (=Princeton's Locality 1000C in part) but is in a slightly older zone. North Wall Quarry has produced only a few specimens.

East Wall Quarry. Situated about 150 feet south of North Wall Quarry on the east side of West Sinclair Draw and on the south-central side of the SW $\frac{1}{4}$, SW $\frac{1}{4}$, SE $\frac{1}{4}$, sect. 3, T. 25 N, R. 55 W, Sioux County, Nebraska. Elevation at bottom of channel 4830 feet; top of channel 4840 feet. Figures 5D, 14, 15.

Synonyms. Wilson (MS, 1932): "West Sinclair Draw, Hor. A, Q. No. 6." Wilson (MS, 1937): "East Wall Quarry."

Repository of Fossils. Frick Collection.

History. Discovered by Wilson in September, 1932, and worked by him in 1932, 1937, and 1939. East Wall Quarry has produced only a small collection. Princeton University photographs taken in 1914 show prospect holes near this site. If any fossils were collected by the Princeton party, their source data would be given as "Locality 1000C."

Douglas Quarry. Situated near the head of Sinclair Draw on the east side and geographically between Jenkins and Version quarries in the center of the NE $\frac{1}{4}$, SW $\frac{1}{4}$, NW $\frac{1}{4}$, SE $\frac{1}{4}$, SW $\frac{1}{4}$, sect. 3, T. 25 N, R. 55 W, Sioux County, Nebraska. Elevation at floor 4820 feet. Figures 2, 5D, 14, 15.

Synonyms. None.

FIG. 15. East and West Sinclair draws showing quarry locations and synonymous names in boxes. This area is shaded in black on figure 2.

Repository of Fossils. Frick Collection.

History. Discovered by Skinner and party in August, 1943, and named for a local rancher, Claude Douglas.

Remarks. Fossils were collected from below a fine, gray, volcanic ash-filled sand. A natural outcrop of these sediments south of Douglas Quarry led to the discovery of the fossil-producing matrix that was sod-covered until opened. There was no indication of prior work.

QUARRIES OF SUBCYCLE 2

Princeton's 1914 Locality 1000C (in part). Situated along both sides of the head of West Sinclair Draw where a small waterfall is active during rainy periods, in the SW $\frac{1}{4}$, SW $\frac{1}{4}$, SE $\frac{1}{4}$, sect. 3, T. 25 N, R. 55 W, Sioux County, Nebraska. Figures 5D, 14, 15.

Synonyms. East Sand Quarry (in part). Princeton University 1914 photographs show only prospect holes. Wilson (MS, 1932); "Chan. C Hor., West Sinclair Draw (West Wall)." Wilson (MS, 1935); "West Surface Q., Chan. C, West Sinclair Draw." Skinner (MS, 1941): West Surface Quarry.

Repository of Fossils. Princeton University; Department of Vertebrate Paleontology and Frick Collection, the American Museum of Natural History.

History. Sinclair (1915, p. 74) cited an area comprised of "T. 25 N., R. 55 W., Sec. 3 (SE $\frac{1}{4}$ to middle of section)" as the boundaries of Locality 1000C. This included the entire area shown on the map (fig. 2) of East and West Sinclair draws as named by Matthew (1924a) and as used in the present paper. Locality 1000C also included the top of Olcott Hill, although the main workings were around the head of West Sinclair Draw (fig. 15).

Remarks. Princeton's Locality 1000C included a nonzoned collection from all parts of the Olcott Formation as well as specimens from the Laucomer Member of the Snake Creek Formation at the top of Olcott Hill.

Sinclair Quarry. Situated on the west side of West Sinclair Draw, slightly south of but part of the main workings of Princeton's Locality 1000C. Figures 5D, 14, 15.

Synonyms. Sinclair (1915); "Princeton's Locality 1000C" (in part). Thomson (MS.d, 1921):

"Sinclair Draw Q." (in part). Osborn (1936, fig. 392): "Sinclair Draw Quarry." Skinner (MS, 1941): Sinclair Quarry.

Repository of Fossils. Princeton University; Department of Vertebrate Paleontology, Frick Collection, the American Museum of Natural History.

History. Neither Wilson nor Skinner worked this quarry.

East Sand Quarry. The southernmost quarry on the east side of West Sinclair Draw, situated near the center of the north line of the NW $\frac{1}{4}$, NW $\frac{1}{4}$, NE $\frac{1}{4}$, sect. 10, T. 25 N, R. 55 W, Sioux County, Nebraska. Elevation at floor 4810 feet; at top, 4825 feet. Figures 5D, 14, 15.

Synonyms. Sinclair (1915): "Princeton's Locality 1000C" (in part). Wilson (MS, 1932): "Sub A." Wilson (MS, 1933): "Chan. D, East Wall." Wilson (MS, 1937): "East Sand Q. No. 9." Skinner (MS, 1941): East Sand Quarry.

Repository of Fossils. Princeton University may have fossils from the matrix of East Sand Quarry or from nearby. Frick Collection.

Remarks. Fossils were derived from the fill of a channel-trench that had cut through the sandy volcanic ash-filled silt of Subcycle 1 of the Olcott Formation and through the transitional zone between the Harrison and Olcott formations. Princeton's 1914 photographs show diggings at this site, but nothing is known as to the number of fossils they collected. A large volume of matrix was removed by the Skinner party to obtain a moderate-sized collection.

West Sand Quarry. Situated on the west side of West Sinclair Draw on a south-facing bluff, in the south half of the SW $\frac{1}{4}$, SW $\frac{1}{4}$, SW $\frac{1}{4}$, SE $\frac{1}{4}$, sect. 3, T. 25 N, R. 55 W, Sioux County, Nebraska. Elevations of known depth of channel deposit are from 4810 to 4825 feet. Figures 5D, 14, 15.

Synonyms. Wilson (MS, 1932): "Chan. D, West Sinclair Draw." Wilson (MS, 1937): "West Sand Q., No. 8." Skinner (MS, 1941): West Sand Quarry.

Repository of Fossils. Frick Collection.

History. Some of Princeton's 1914 Locality 1000C fossils are probably from here and Whitford may have again worked this quarry in 1916 for the American Museum. Outcrops immediately to the north were called "Sinclair quar-

ries." Wilson, however, developed West Sand and worked it in 1932, 1937, and 1940. In the 1940s Skinner made an extensive excavation at this site by using pulleys, a Model A Ford pickup, and a scraper.

Remarks. West Sand Quarry is overlain by volcanic ash and clay as in East Sand Quarry. Cook considered that this ash was in the Sheep Creek Formation. At the time Skinner packed the Cook Collection for shipment to the American Museum, he found a sample bag that Cook had labeled: "Volcanic ash, Sinclair Draw, Sheep Creek beds (west side of draw) H. J. Cook, Collector, May 6, 1962." The bag contained a white ash similar to that found above West Sand Quarry, and unlike the bluish gray ash of the Sheep Creek Formation on the head of *Aphelops* Draw.

In 1958 Cook (MS) referred four specimens to the "Sheep Creek beds" in the Sinclair draws: (1) A horse maxilla (HC 1163) and (2) a horse ramus (HC 1164) from East Sinclair Draw, both of which are part of the exhibit at the Agate Fossil Beds National Monument. From "Sinclair Draw" (=West Sinclair Draw, present paper) Cook collected (3) a carnivore premolar, HC 1169 (=AMNH 81527) and (4) a partial turtle carapace, HC 1170 (=AMNH 8334). Cook's identification of the white sandy clay including an inch of white ash in the channel-trench of Subcycle 2 as "Sheep Creek" was on the premise that he had a Sheep Creek ash.

Sand Quarry. An extension of West Sand Quarry that is situated at the head of a short, north-trending draw in West Sinclair Draw. Sand Quarry is a small, U-shaped outcrop in the southwest corner of the SW $\frac{1}{4}$, SE $\frac{1}{4}$, sect. 3, T. 25 N, R. 55 W, Sioux County, Nebraska. Elevations of the known depth of the channel deposit are from 4810 to 4825 feet. Figures 5D, 14, 15.

Synonyms. None.

Repository of Fossils. Frick Collection.

History. Discovered and worked by Wilson in 1940.

Remarks. Sand Quarry is in a northwesterly extension of the channel-trench that the Sand quarries occupy. Lithic relationships are clear because the deposits are less than 75 feet from West Sand Quarry. The fill at Sand Quarry yielded only a few fossils.

Jenkins Quarry. Situated on the east side of Sinclair Draw at the south side of the entrance of the first side wash, and on the west-central side of the SW $\frac{1}{4}$, SE $\frac{1}{4}$, SW $\frac{1}{4}$, SW $\frac{1}{4}$, sect. 3, T. 25 N, R. 55 W, Sioux County, Nebraska. Elevations: Floor 4810 feet; top of channel 4837 feet. Figures 2, 5D, 14.

Synonyms. None.

Repository of Fossils. Frick collection.

History. Discovered by and named for Richard Jenkins, a member of Wilson's party, in August, 1940. Worked by Skinner in the 1940s.

Remarks. Jenkins Quarry is presumed to be in the same sand-filled channel-trench of Subcycle 2 as East and West Sand quarries, and although the stratigraphic sequence at Jenkins Quarry is not so clear, it still enabled us to define the extension of the channel deposits contained within the trench. There is little evidence of the superposition of deposits that carry Surface Quarry sediments of Subcycle 3. While Jenkins Quarry was being worked, the erosional contact of the deposits with the underlying Harrison Formation was exposed. East and West Jenkins quarries are extensions in the vicinity of the main Jenkins Quarry.

East Jenkins Quarry. Situated in an east fork of Sinclair Draw, about 100 yards north-northeast of Jenkins Quarry, in the east half of the NW $\frac{1}{4}$, SW $\frac{1}{4}$, SE $\frac{1}{4}$, SW $\frac{1}{4}$, sect. 3, T. 25 N, R. 55 W, Sioux County, Nebraska. Elevation of floor is more than 4805 feet because the bottom was not exposed. Figures 2, 5D, 14.

Synonyms. None.

Repository of Fossils. Frick Collection.

History. Discovered by Skinner and party in June, 1942.

Remarks. The direction of the channel-trench had been determined before this site was opened, even though it was sod covered and gave no evidence of fossils. An opening was made through the sod on the north side of the draw and on the south side of the trench where the loose sand fill contacted the harder retaining transitional zone and the Harrison Formation. The bottom of the trench was never reached.

West Jenkins Quarry. Situated on the west side of Sinclair Draw, a short distance northwest

of Jenkins Quarry, in the northwest corner of the SW $\frac{1}{4}$, SE $\frac{1}{4}$, SW $\frac{1}{4}$, sect. 3, T. 25 N, R. 55 W, Sioux County, Nebraska. Elevations: Floor 4810 feet; top of channel 4837 feet. Figures 2, 5D, 14.

Synonyms. None.

Repository of Fossils. Frick Collection.

History. Skinner opened this quarry in June, 1942, and collected a few specimens from it during the 1940s.

Remarks. West Jenkins Quarry was never fully developed. The fossil-producing fill was covered by at least 8 feet of windblown surface deposits that made quarrying impractical.

Pocket 34. Situated on the west side of Sinclair Draw northwest of Jenkins Quarry on the north-central side of the SE $\frac{1}{4}$, SW $\frac{1}{4}$, SW $\frac{1}{4}$, sect. 3, T. 25 N, R. 55 W, Sioux County, Nebraska. Elevation at floor 4825 feet. Figures 2, 5D, 14.

Synonyms. None.

Repository of Fossils. Frick Collection.

History. Discovered by Wilson in August, 1940.

Remarks. Pocket 34 is a small site that contains many bone fragments and is believed to be part of the same deposit as Jenkins Quarry. This site, which is a western extension of the fossil-producing deposits west of Sinclair Draw, was not worked beyond the initial exploration.

QUARRIES OF SUBCYCLE 3

AMNH 1908 Quarry. Situated in the northeastern part of East Sinclair Draw, on the west-central side of the NW $\frac{1}{4}$, NE $\frac{1}{4}$, NW $\frac{1}{4}$, NE $\frac{1}{4}$, sect. 10, T. 25 N, R. 55 W, Sioux County, Nebraska. Elevation about 4840 feet. Figures 5D, 14-16.

Synonyms. Probably 1908 Quarry 2. See table 4.

Repository of Fossils. Department of Vertebrate Paleontology, the American Museum of Natural History.

History. The exact site of this small excavation is verified by a labeled photograph (AMNH 18358) that Osborn (1910, fig. 162) published and is one of two 1908 sites that were documented photographically. The other site is near the top of Olcott Hill that Cook (1922c, pp. 1-2) and Matthew (1923a, pp. 11-12) considered to

be the type locality of the Snake Creek Formation.

With the photograph in hand we determined that AMNH 1908 Quarry was from 10 to 20 feet north of the later workings of Far Surface Quarry (fig. 15). Thomson's field map (fig. 16) also shows a site in the northwest part of West Sinclair Draw for the 1908 work, indicating that the 1908 collection was made from all parts of the Olcott Formation in East and West Sinclair draws.

Mesoceras Quarry. Situated at the head of West Sinclair Draw in the central part of the SW $\frac{1}{4}$, SW $\frac{1}{4}$, SE $\frac{1}{4}$, sect. 3, T. 25 N, R. 55 W, Sioux County, Nebraska. Figures 5D, 14, 15.

Synonyms. None.

Repository of Fossils. Cook Collection, the American Museum of Natural History.

History. Discovered by Harold Cook and his brother, James, on February 12, 1925.

Remarks. Cook (MS) described the site where he collected the type of *Teleoceras* (*Mesoceras*) *thomsoni* as in "Sinclair Draw [Wilson's West Sinclair Draw] at head of draw, in the bottom of the sharp sand deposits of the Snake Creek Beds [Olcott Formation, present report] just above the contact with the cemented Sheep Creek Beds [=Harrison Formation, present report]." Cook (MS) used *Mesoceras* Quarry as a reference point for subsequently collected specimens. Thomson's field map (fig. 16) shows this quarry, but neither Cook nor Thomson gave the exact geographic position.

East Surface Quarry. Situated on the west side of the northwest head of East Sinclair Draw in the northeast corner of the NW $\frac{1}{4}$, NW $\frac{1}{4}$, NE $\frac{1}{4}$, sect. 10, T. 25 N, R. 55 W, Sioux County, Nebraska. Elevations: Lower part of channel 4830 feet; top of channel 4845 feet. Figures 5D, 14, 15.

Synonyms. Whitford (MS.b, 1916): "Snake Cr. Beds." Thomson (MS.d, 1921); "Quarry A." Matthew (1924a, fig. 1): "1916-21" workings. Wilson (MS, 1932): "Sinclair Q., No. 2, Hor. C." Osborn (1936, fig. 392): "Quarry 2" (in part). Wilson (MS, 1937): "East Surface Q. No. 2." Skinner (MS, 1941): "East Surface Quarry."

Repository of Fossils. Department of Verte-

brate Paleontology and Frick Collection, the American Museum of Natural History.

History. Discovered by Whitford and Stoll in 1916 on the American Museum expedition.

Remarks. East Surface Quarry has a larger working area than any other site in East or West Sinclair draws; the sediments belong to Subcycle 3. Without the evidence gained from the sequence exposed at East Sand Quarry in West Sinclair Draw, this placement would be questionable. At East Surface Quarry deposits of Subcycle 3 rest directly on the gray volcanic ash-filled sand of Subcycle 1. The intervening loose channel sand of Subcycle 2 is not present as it is at East Sand Quarry. Elsewhere in East Sinclair Draw, Subcycle 2 is present, but not exposed.

West Surface Quarry. Situated on the west side of West Sinclair Draw near the gully at the head of the draw that has a small waterfall during rainy seasons. West Surface Quarry, which is just north of West Sand Quarry, is the westward extension of Princeton's 1914 Locality 1000C and is in the SW $\frac{1}{4}$, SW $\frac{1}{4}$, SE $\frac{1}{4}$, sect. 3, T. 25 N, R. 55 W, Sioux County, Nebraska. Elevations are the same as for Far Surface Quarry: Lower part of channel 4830 feet; top of channel 4845 feet. Figures 5D, 14, 15.

Synonyms. Sinclair (1915): Princeton Locality 1000C included West Surface Quarry. Wilson (MS, 1932): "Chan. C. Hor., West Sinclair Draw (West Wall)." Wilson (MS, 1935): "West Surface Q., Chan. C., West Sinclair Draw." Skinner (MS, 1941): "West Surface Quarry."

Repository of Fossils. Princeton University; Frick Collection.

History. In 1914 Whitford and Barner worked the area that contains West Surface and East Sand quarries; Wilson worked West Surface Quarry extensively from 1932 to 1940, and Skinner in 1946 and 1947.

Remarks. West Surface Quarry is situated in a thicker part of the channel left during deposition of Subcycle 3.

Far Surface Quarry. Situated on the east side of East Sinclair Draw on the west-central side of the NE $\frac{1}{4}$, NW $\frac{1}{4}$, NE $\frac{1}{4}$, sect. 10, T. 25 N, R. 55 W, Sioux County, Nebraska, directly above Camel Quarry, and between, but stratigraphically higher than, Snake and Trojan quarries. Eleva-

tions are the same as those of West Surface Quarry: Lower part of channel 4830 feet; top of channel 4845 feet. Figures 5D, 14, 15.

Synonyms. Whitford (MS.b, 1916): "Snake Cr. Beds" but no site specifically named. Thomson (MS.d, 1921): "Quarry B." Matthew (1924a, fig. 1): "Quarry 21" (in part). Wilson (MS, 1932): "Q. No. 3, Hor. C." Osborn (1936, fig. 392): "Quarry 2" (in part). Wilson (MS, 1938): "Q. No. 3, Hor. C." Wilson (MS, 1941): "Far Surface Q. No. 3." Skinner (MS, 1941): "Far Surface Quarry."

Repository of Fossils. Department of Vertebrate Paleontology and Frick Collection, the American Museum of Natural History.

History. Whitford worked Far Surface Quarry in 1916, Thomson reopened it in 1921, Wilson made a small collection in 1932 and a large one in 1938. Skinner did not work Far Surface Quarry.

Remarks. The many names applied to this quarry have tended to dissipate the fauna, which is a large one.

New Surface Quarry. Situated on the west side of East Sinclair Draw on a south-facing rim in the central part of the NW $\frac{1}{4}$, NW $\frac{1}{4}$, NE $\frac{1}{4}$, sect. 10, T. 25 N, R. 55 W, Sioux County, Nebraska. Elevations: Lower part of channel 4835 feet; upper part of channel 4845 feet. Figures 5D, 14, 15.

Synonyms. None.

Repository of Fossils. Frick Collection.

History. New Surface Quarry, which Wilson opened in 1938, is a southward extension of Thomson's "Quarry A" that in turn equals East Surface Quarry.

Version Quarry. Situated on the head of the most northerly branch of Sinclair Draw on the east-central side of the NW $\frac{1}{4}$, NW $\frac{1}{4}$, SE $\frac{1}{4}$, SW $\frac{1}{4}$, sect. 3, T. 25 N, R. 55 W, Sioux County, Nebraska. Elevation of sod above quarry 4827 feet. Figures 2, 5D, 14.

Synonyms. None.

Repository of Fossils. Frick Collection.

History. Discovered by Wilson in September, 1936, but never worked by Skinner.

Remarks. So far as can be determined from the outcrops in the old workings, Version Quarry is in Subcycle 3.

New Sand Quarry. Situated on an east-facing bank on the west side of West Sinclair Draw in the southeast corner of the SE $\frac{1}{4}$, SE $\frac{1}{4}$, SW $\frac{1}{4}$, sect. 3, T. 25 N, R. 55 W, Sioux County, Nebraska. The elevation at the bottom of the channel is not known; top of the channel is ± 4820 feet. Figures 5D, 14, 15.

Synonyms. None.

Repository of Fossils. Frick Collection.

History. Discovered by Wilson in 1938. Only five specimens have been taken from New Sand Quarry.

Remarks. Despite the name, New Sand Quarry is not in the fluvial deposit that carries the East and West Sand quarries. The fossils are derived from overlying sediments that are related to the Surface Quarry deposits.

QUARRIES IN THE OLCOTT FORMATION RELATION TO SUBCYCLES UNKNOWN

Echo Quarry. Extends along the bottom of Antelope Draw, mainly on the south side, for 1500 feet. The channel deposits are in the southeastern part of the SE $\frac{1}{4}$, NE $\frac{1}{4}$, SE $\frac{1}{4}$, sect. 33, T. 26 N, R. 55 W, Sioux County, Nebraska. Elevation from 4770 feet to 4800 feet. Figures 2, 4A, 14.

Synonyms. Wilson (MS, 1934): "Campsite-Echo Quarry, Antelope Draw," and "East side Echo Quarry, Antelope Draw." Wilson (MS, 1939): "Echo Quarry, Echo Valley Channel Bed, Antelope Draw." Skinner (MS, 1941): "Echo Quarry."

Repository of Fossils. Frick Collection.

History. Discovered by Wilson and party in 1934 and worked by him until 1940. Echo Quarry was worked extensively in the 1940s by Skinner and party.

Remarks. Wilson's field cabin was situated at the junction of the main branch of Antelope Draw and a prominent south-trending draw where the lower part of the Sheep Creek Formation is exposed along the south side of the draw. The tan to buff Sheep Creek sediments exposed here once formed the south side of the gulch into which Echo Quarry sediments were deposited.

The degradation phase of the paleostream that cut the fluvial trench must have eroded through at least 180 feet of Sheep Creek Formation

(elevation 4945 to 4770 feet) before cutting into the underlying Harrison Formation at the mouth of Antelope Draw. Large tabular concretionary layers within the typical gray "salt and pepper" sand of the Harrison Formation are now exposed along the sides of the recent wash.

With the exception of a colt skeleton, the fossils are disarticulated cranial and postcranial elements, most of which are not waterworn, indicating that the remains in the lower part of the channel had not been moved far. This is in contrast to the many examples of articulation in specimens from Mill Quarry that were taken primarily from fine, well-sorted sand resting on a sandy volcanic ash layer (fig. 4A).

Humbug Quarry. Situated on the hill on the south side of Ranch House Draw near the center of the NW $\frac{1}{4}$, NW $\frac{1}{4}$, sect. 3, T. 25 N, R. 55 W, Sioux County, Nebraska. Elevation of top above Humbug Quarry proper 4838 feet; floor of Humbug Quarry 4826 feet. Figures 2, 4A, 14.

Synonyms. None.

Repository of Fossils. Frick Collection.

History. Discovered by Wilson and party on October 18, 1936.

South Humbug Quarry. Situated in the southwest part of the NW $\frac{1}{4}$, NW $\frac{1}{4}$, sect. 3, T. 25 N, R. 55 W, Sioux County, Nebraska, and on a ridge south of Humbug Quarry. Elevation of floor 4826 feet. Figures 2, 4A, 14.

Synonyms. None.

Repository of Fossils. Frick Collection.

History. Discovered by Skinner and party in 1941.

Remarks. Applicable to Humbug and South Humbug quarries. Exposures of the fossil-bearing matrix in both quarries are limited. Fossilization is predominantly black-brown, noticeably different from that of any other quarry in the Olcott Formation. Limited exposures in the drainage southeast of Humbug Quarry suggest that the deposits rest directly on a Harrison "high" as shown in Figure 4A. Both quarries were refilled according to contract with the landowner and are barely discernible on the surface.

Most of the Humbug Quarry collection was made by Wilson's party. Skinner's party opened up an exploratory trench 15 to 20 feet wide and 30 to 40 feet long south of Humbug Quarry.

Although the same sandy, fine, silty (and dusty) matrix was present in the southern extension, it was nearly unfossiliferous, except for a *Paracosoryx* skull in fine condition.

Mill and Floor of Mill Quarries. Situated just below the junction of two forks in the extreme head of the wash in Antelope Draw in the NW $\frac{1}{4}$, SE $\frac{1}{4}$, sect. 33, T. 26 N, R. 55 W, Sioux County, Nebraska. Elevation at floor +4808 feet. The fossiliferous matrix of Mill Quarry is 8 to 10 feet above the floor. Figures 2, 4A, 14.

Synonyms. None.

Repository of Fossils. Frick Collection.

History. Discovered by Skinner and party in 1942. Large collections were made from both Mill and Floor of Mill quarries, but Floor of Mill specimens were not collected until 1947.

Remarks. Mill Quarry, which is about $\frac{1}{4}$ mile from the closest Echo Quarry channel deposit, seems to represent the terminal phase of the Echo Quarry paleovalley fill. (See Olcott Formation Lithology, p. 302.) Small dry washes along both sides of Antelope Draw have exposed the Sheep Creek Formation between Mill and Echo quarries. In the immediate vicinity of Mill Quarry headward erosion has weathered out 6 to 8 feet of Recent fill, so that only those sediments that are at the extreme bottom of the wash can be examined. The fossiliferous matrix of Mill Quarry is composed of fine, well-sorted sand, volcanic ash, and some clay, such as that left by a slow-moving stream. The Floor of Mill Quarry is composed of a fossiliferous layer of fine, consolidated, gray sandy ash (fig. 4A inset). The outcrops are such that it could not be determined if the Floor of Mill was a consolidated lens within the channel deposit, therefore, the fossils were kept separate from those of Mill Quarry proper.

The fossils from Mill Quarry seem to represent some of the latest forms derived from the local area, yet they carry the typical Lower Snake Creek faunal complex. The faunal difference may reflect a different depositional environment. Mill Quarry has produced many articulated specimens, in contrast to Echo Quarry which had almost no articulated specimens. Most of the specimens remain undescribed, except for field identification.

Prosynthetoceras Quarry. Situated in the northeast corner of the NE $\frac{1}{4}$, NE $\frac{1}{4}$, sect. 4, T.

25 N, R. 55 W, Sioux County, Nebraska, in a branch of Ranch House Draw above Greenside Quarry (fig. 2). Elevation at floor 4830 feet; at top of quarry 4845 feet. Figures 2, 4A, 14.

Synonyms. Skinner (MS, 1941): "*Synthetoceras* Quarry," but changed at Frick's request to "*Prosynthetoceras* Quarry."

Repository of Fossils. Frick Collection.

History. Discovered by Skinner and party in September, 1941.

Remarks. *Prosynthetoceras* Quarry directly overlies Greenside Quarry, and is in a narrow isolated channel that is incised into the Sheep Creek Formation. The unconsolidated, well-sorted, fluvial sediments cannot be lithically correlated with any of the three subcycles although they are characteristic of the Olcott Formation. *Prosynthetoceras* Quarry is believed to be later than nearby Humbug Quarry, but there is no lithic evidence for this assignment.

Due to the nature of the surrounding terrain, it was not possible to develop extensive explorations of this channel deposit. The fossil-producing matrix contained large blocks of Sheep Creek Formation. The quarry yielded a well-fossilized partial skull of *Prosynthetoceras* and the skull of an exceptionally large amphi-*cyonid*.

Grass Roots Quarry. Situated on a northern extension of Olcott Hill near the center of the NE $\frac{1}{4}$, NW $\frac{1}{4}$, SE $\frac{1}{4}$, sect. 3, T. 25 N, R. 55 W, Sioux County, Nebraska. Elevation 4865 feet. Figures 2, 4A, 14.

Synonyms. Thomson's map (fig. 16): "Grass Roots Qu. '25, HFO Q. 6." Osborn (1936, fig. 392): "Quarry 6. Grass Roots Quarry."

Repository of Fossils. Department of Vertebrate Paleontology, the American Museum of Natural History.

History. Thomson (MS.h, 1926) stated that, "We began our work by opening a prospect which we discovered in 1925 known as Grass Roots Quarry or Quarry number 6. In a few days we had exhausted this quarry."

Frick Laboratory parties did not work this quarry. It was not until Skinner discovered Thomson's map (fig. 16) that the location was known.

Remarks. Osborn (1936, fig. 392) showed Grass Roots Quarry in about the correct relative

position, but 100 feet lower than the top of Olcott Hill. Our elevations show only 54 feet difference in elevation. The fossil-bearing deposits are slightly higher than the fossil deposits shown on figure 5D. Osborn placed Grass Roots Quarry (his Quarry 6) in "Snake Creek A, lower, . . . *Merychippus paniensis* zone."

A stratigraphic study shows that this quarry is in the Olcott Formation in a massive, loose sand that is overlain by a gray, silty, rust-stained sand. The quarry, which is completely surrounded by sod cover, is within sight of Kilpatrick Quarry to the southwest and Olcott Hill to the south.

Boulder Quarry. Situated at the base of Olcott Hill on the northeast face, and on the north-central side of the SE $\frac{1}{4}$, SE $\frac{1}{4}$, sect. 3, T. 25 N, R. 55 W, Sioux County, Nebraska. Elevation at floor 4814 feet. Figures 2, 5D, 14.

Synonyms. None.

Repository of Fossils. Frick Collection.

History. Discovered by Skinner and party on September 16, 1942, while making a strati-

graphic section of the outcrops on the northeast face of Olcott Hill.

Remarks. Boulder Quarry is in the basal part of the type section of the Olcott Formation. Large, unrelated slump blocks, for which the quarry was named, were exposed in the sod, but there was no surface indication of the unconsolidated, well-sorted sand that makes up the fossiliferous deposits of Boulder Quarry. At the bottom of the exposures and near the mouth of the wash, was a small outcrop that was interpreted as the top of the weathered Harrison Formation, because it was lithically similar to outcrops in the Sinclair draws. An exploratory hole lateral to this Harrison outcrop revealed an unconsolidated, well-sorted sand similar to that in East and West Sand quarries. Only when Boulder Quarry was opened was it evident that it was in a channel-trench and that the overlying sedimentary slump blocks had no relation to the quarry deposit, but were derived from the much later massive, reddish tan sand of the Murphy Member of the Snake Creek Formation (p. 308).

QUARRIES IN THE SNAKE CREEK FORMATION

LAUCOMER MEMBER (NEW) OF THE SNAKE CREEK FORMATION

MEDIAL MIOCENE (EARLY CLARENDONIAN)

Kilpatrick Quarry. Situated on the northwest part of Olcott Hill on the north-central side of the SW $\frac{1}{4}$, NW $\frac{1}{4}$, SE $\frac{1}{4}$, sect. 3, T. 25 N, R. 55 W., Sioux County, Nebraska. Elevation near quarry 4904 feet. Figures 2, 4A, 14.

Synonyms. Thomson (MS.h, 1926): "Kilpatrick Quarry. H.F.O. Qu. 7." Osborn (1936, fig. 392): "Quarry 7 Kilpatrick." Wilson (MS, 1938): "Thomson's *Hipparion* Quarry."

Repository of Fossils. Department of Vertebrate Paleontology and Frick Collection, the American Museum of Natural History.

History. Discovered by Thomson in July, 1925. Wilson collected very little in this quarry and Skinner made no collections at this site.

Remarks. Kilpatrick Quarry is a northwestern extension of the original 1908 discovery site on the north face of Olcott Hill; the surrounding area is completely sod covered. Kilpatrick Quarry

is closer to the Harrison "high" situated to the northwest than other fossil sites near, or on Olcott Hill. Skinner dug into the working face to determine the composition of the fossil-producing matrix and to examine the "floor" of the deposit. The matrix is clearly a part of the Laucomer Member, whereas the floor is composed of well-consolidated sand that closely resembles the Murphy Member of the Snake Creek Formation.

Fossils from Kilpatrick Quarry are a part of the Snake Creek Fauna.

***Hesperopithecus* Site** (not a quarry). Situated just northeast of the extreme top of Olcott Hill at the head of an abrupt wash that heads northeasterly toward Boulder Quarry (part of the type section of the Olcott Formation). The site is in the northwest corner of the SE $\frac{1}{4}$, SE $\frac{1}{4}$, sect. 3, T. 25 N, R. 55 W, Sioux County, Nebraska. It is also south of the east-west line between the former Ashbrook and Kilpatrick pastures (on the Ashbrook side) mentioned in the early Thomson letters. Figures 2, 5D. See Landowners' map (fig. 17).

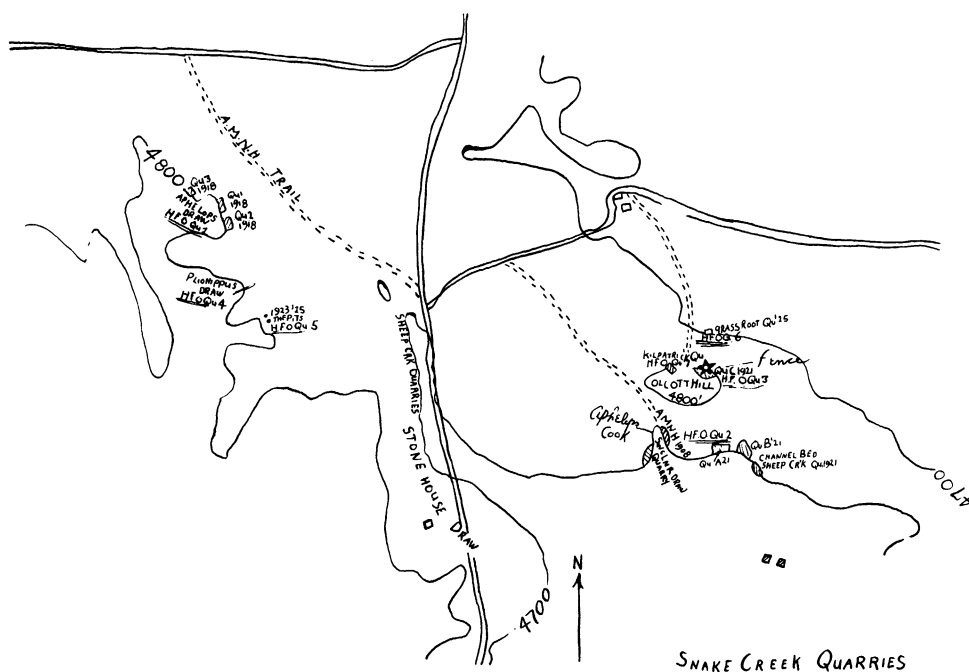


FIG. 16. Albert Thomson's map of the Sheep Creek-Snake Creek area made after 1926 (no date). Archives, Department of Vertebrate Paleontology, the American Museum of Natural History. Part of Thomson's map was reproduced in Osborn (1936, fig. 392).

Synonyms. "AMNH Locality 1908 to 1927" identified by photograph AMNH 18358. Sinclair (1915): "Princeton Locality 1000C" in part. Thomson (MS.d, 1921): "Quarry C, Ashbrook Pasture." Matthew (1924a, fig. 1): "*Q." Wilson (MS, 1933): "Channel Z." Osborn (1936, fig. 392): "Quarry 3." Cook (MS): "Where type of *Hesperopithecus haroldcookii* was found."

Repository of Fossils. Princeton University; Department of Vertebrate Paleontology and Frick Collection, the American Museum of Natural History.

History. This is where Cook collected the controversial "anthropoid" tooth in July, 1917, and which Osborn (1922) described as *Hesperopithecus haroldcookii* (= *Prosthennops haroldcookii*, present paper, p. 355). The site is identified by an iron stake and by a 1925 photograph in the Cook Collection at Agate showing Harold Cook standing with Prof. Othenio Abel from the University of Vienna, Austria. See Historical Review, page 282.

Remarks. Cook drove an iron stake deeply into the massive red silt and sand of the Murphy Member that directly underlie the lag concentrate of the outwash of the Laucomer Member gravel. The fossils were collected from the Laucomer Member channel that extends from the Olcott Quarry on the east end of Olcott Hill northwesterly to the brow of Olcott Hill and beyond to the Kilpatrick Quarry. The Olcott and Kilpatrick quarries are also in the Laucomer Member of the Snake Creek Formation.

Olcott Quarry. Situated on the east end of Olcott Hill on the north side of a promontory in the center of the SE $\frac{1}{4}$, SE $\frac{1}{4}$, SE $\frac{1}{4}$, sect. 3, T. 25 N, R. 55 W, Sioux County, Nebraska. Elevation at base of channel 4864 feet. Figures 2, 5D.

Synonyms. Wilson (MS, 1936): "Olcott Quarry, *Hipparion* Channel Bed." Skinner (MS, 1946): "Olcott Quarry, *Hipparion affine* Channel."

Repository of Fossils. Frick Collection.

History. Discovered by Wilson and party in September, 1936.

Remarks. Olcott Quarry is situated on the extreme eastern end of Olcott Hill, well separated from the outcrops on the north face where the 1908 exploration and later American Museum work was carried on. The fossils were

derived from the Laucomer Member in the lower part of a channel-trench that had been cut deeply into the Murphy Member of the Snake Creek Formation. At the quarry both sides of the trench are outlined by the resistant reddish sandstone of the Murphy Member where it is exposed above the sod and defines the course of the sand and rubble-filled trench.

THE LOWER PART OF THE JOHNSON MEMBER (NEW) OF THE SNAKE CREEK FORMATION

LATE MIOCENE (EARLY HEMPHILLIAN)

The Aphelops Quarries. Thomson's map (fig. 16) shows three quarries, which he numbered 1, 2, and 3 at the head of *Aphelops* Draw in the NE $\frac{1}{4}$, sect. 30, T. 26 N, R. 55 W, Sioux County, Nebraska. Evidence of an old quarry floor can still be seen at this spot (figs. 2, 6E, 14, 16).

Synonyms. In 1914 Princeton's campsite (their Locality 1000A) was directly above the Sheep Creek Ash near the head of *Aphelops* Draw (more westerly than the middle *Aphelops* Quarry, no. 1). A photograph in the Princeton University Archives shows the campsite. Wilson (MS) may have referred to these sites in 1934 when he listed fossils as having been collected from "*Hipparion* channel, *Aphelops* Draw."

Repository of Fossils. Princeton University Collection; Department of Vertebrate Paleontology and Frick Collection, the American Museum of Natural History.

History. The *Aphelops* quarries and *Aphelops* Draw take their names from the discovery in 1918 by Mrs. Albert Thomson of the type of *Aphelops malacorhinus mutilus* (AMNH 17584) in Quarry 1. The date 1918 is important because figure 16 shows Thomson's 1918 quarries 1, 2, and 3, at the head of *Aphelops* Draw, and thus distinguishes them from Thomson's 1908 quarries 1, 2, and 3, on ?Olcott Hill, East Sinclair, and *Pliohippus* draws, and from Osborn's (1936, fig. 392) quarries 2 and 3 on Olcott Hill and East Sinclair Draw, as well as Wilson's quarries 1 through 5 in East Sinclair Draw (see table 4).

The *Aphelops* quarries were never worked by the senior author, nor was he briefed on the area by Wilson's assistants in 1941 or by Thomson.

Remarks. Stratigraphic studies (fig. 6E) show

that the lower part of the Johnson Member of the Snake Creek Formation is in erosional contact with that part of the Sheep Creek Formation which is directly above the Sheep Creek Ash. Surface drift from near *Aphelops* Draw is only from the lower part of the Johnson Member. From 6 to 10 feet of Sheep Creek sediments are exposed here, but are unfossiliferous so far as could be determined. *Merychippus* and *Aphelops* draws are in the same drainage and the *Merychippus* specimens could as easily have come from *Merychippus* Draw as from *Aphelops* Draw, in which case Wilson (MS, 1934) would have listed the fossils as derived from the "Sheep Creek Flood Plain, *Aphelops* Draw."

Aphelops Quarry and The Pits are the main sites from which the *Aphelops* Draw Fauna was derived.

The Pits. Situated on a slight elevation south of the head of East *Pliohippus* Draw, near the head of Pigeon Draw on the south-central side of the NW $\frac{1}{4}$, SW $\frac{1}{4}$, NE $\frac{1}{4}$, sect. 32, T. 26 N, R. 55 W, Sioux County, Nebraska. Elevation at floor 4924 feet. Figures 2, 4C, 14, 16.

Synonyms. Thomson (MS.f, 1923): "The Pits. H.F.O. Qu. 5." Osborn (1936, fig. 392): "Quarry 5." Cook (MS): "South of *Pliohippus* Draw." Skinner (MS, 1941): "The Pits."

Repository of Fossils. Most of the collection from The Pits is in the Department of Vertebrate Paleontology, a few specimens are in the Cook and Frick collections, the American Museum of Natural History.

History. In a letter to Matthew (July 21, 1923) Thomson said: "The past few days we made a good sized hole prospecting a Snake Creek deposit I located last fall. It is an upper

Snake Creek deposit, but the material was very broken up, horse teeth galore, some are the largest I have ever seen . . . There is no stripping necessary as the bone layer begins just in the grass roots and pockets out in all directions and often downward 3 or 4 feet."

Remarks. The Pits are in the lower part of the Johnson Member of the Snake Creek Formation.

They are completely surrounded by sod-covered prairie. Although Skinner did not collect from these closely situated spots, he collected a few fossils from the weathered dump and quarry walls. The Pits are the source of some of Osborn's proboscidean types (present paper, p. 356). Most of the *Aphelops* Draw Fauna came from this site.

THE UPPER PART OF THE JOHNSON MEMBER (NEW) OF THE SNAKE CREEK FORMATION

LATE MIOCENE (LATE HEMPHILLIAN)

Cook's Pliohippus Quarry. Situated on the east head of East *Pliohippus* Draw in the northeast corner of the NW $\frac{1}{4}$, sect. 32, T. 26 N, R. 55 W, so close to the line between sections 29 and 32 that the site could be in the southeast corner of the SW $\frac{1}{4}$, sect. 29, T. 26 N, R. 55 W, Sioux County, Nebraska. Elevation at floor, about 4940 feet. Figures 2, 4C, 7F, 14, 16.

Synonyms. Matthew (1924a, fig. 1): "*Pliohippus* Draw." Osborn (1936, fig. 392): "Quarry 4." Cook (MS): "*Pliohippus* Draw where I found the *Pliohippus leidymanus* skeleton." Skinner (MS, 1941): Cook's "*Pliohippus* Quarry."

Repository of Fossils. Department of Vertebrate Paleontology, Cook and Frick collections, the American Museum of Natural History.

History. The name *Pliohippus* Draw was for an articulated horse skeleton that Cook collected in 1916 and that Osborn (1918) described as *Pliohippus leidymanus* (= *Dinohippus leidymanus*).

Skinner located the site from photographs (AMNH 1650/101786) in the American Museum, Department of Vertebrate Paleontology Archives).

Remarks. In a strict sense, this is not a quarry, for the deposits that yielded the horse skeleton produced only a few fossils. The entire set of deposits in the vicinity, however, are fossiliferous; the American Museum and Frick parties obtained many fossils from outcrops. Cook (MS) used the site as a reference point for zoning fossils he found in *Pliohippus* Draw, as well as draws to the west.

Cook's *Pliohippus* Quarry overlies the cross-bedded sandy fill of the slump block area (fig. 7F), but is intermediate between the sandy fill and the exposed higher channels that also yielded a part of the ZX Bar Local Fauna. See present paper (p. 313) for a discussion of the Johnson Member and Cook's *Pliohippus* Quarry.

SYSTEMATICS

Figure 14

The following lists give only a part of the faunas from the Sheep Creek and Olcott formations and reflect only a small part of the American Museum, Frick, and Cook collections from the area. In the Sheep Creek and Lower Snake Creek faunas, we list most of the fossils that have appeared in previous publications. Whenever such information could be gleaned, we assigned these specimens to the proper quarry site, thereby providing them with a place in space as well as time. This is possible because the faunal assem-

blages and quarries are arranged according to their place in the rock sequence.

The revised Snake Creek Formation includes two faunas and two local faunas: (1) the Early Clarendonian unnamed local fauna from the Murphy Member, (2) the Late Clarendonian Snake Creek Fauna from the Laucomer Member, (3) the Early Hemphillian *Aphelops* Draw Fauna from the lower part of the Johnson Member, and (4) the Late Hemphillian ZX Bar Local Fauna from the upper part of the Johnson Member. The Snake Creek Fauna includes some fossils that

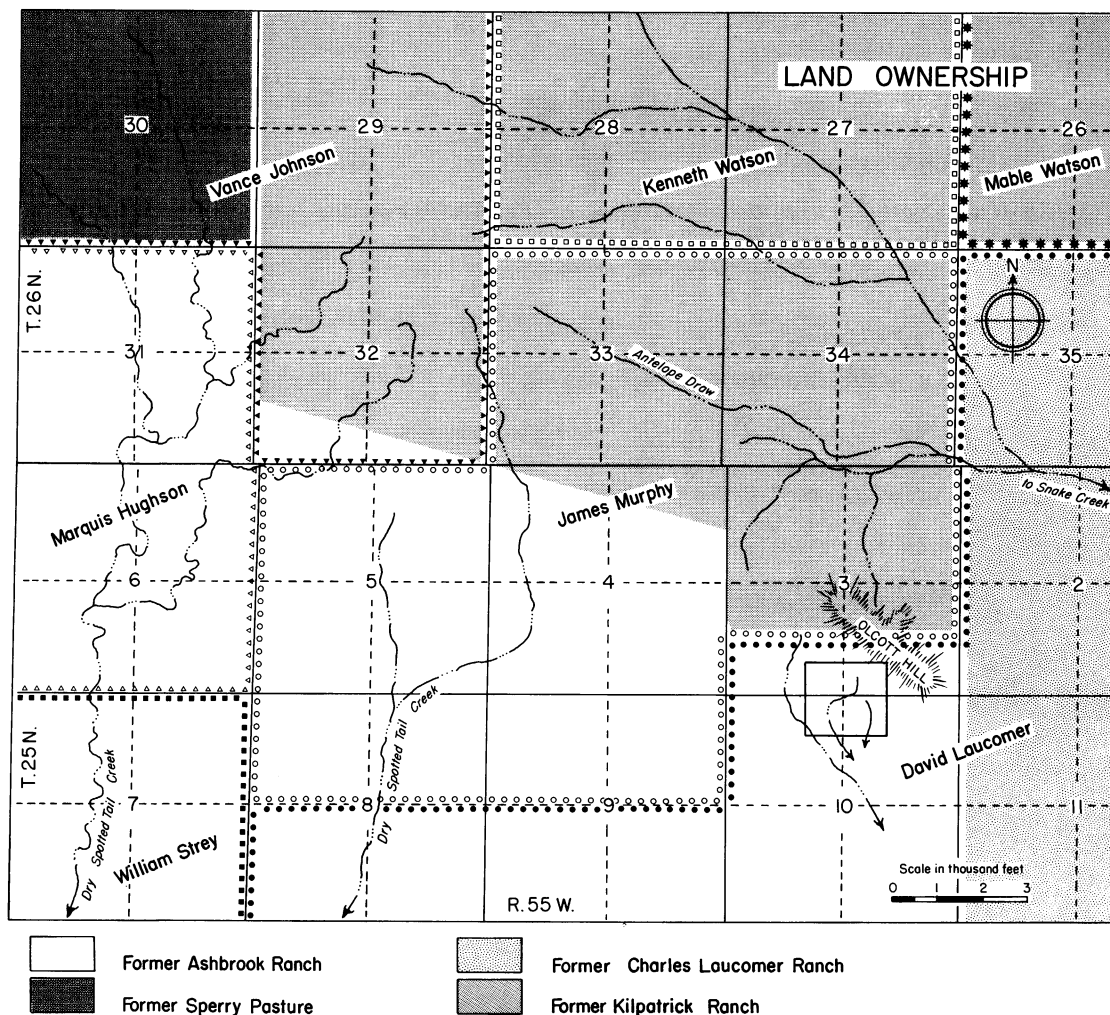


FIG. 17. Previous and current landowners in the Sheep Creek-Snake Creek area, Sioux County, Nebraska.

have not appeared in previous publications as well as those that have been published. By this means attention is drawn to the taxonomic similarity of the Clarendonian fossils from the Murphy and Laucomer members. At the same time Hemphillian fossils from the Johnson Member are shown as relicts (e.g., *Ustatochoerus*, *Leptarctus*) from Clarendonian time, or as new arrivals (e.g., *Neotragocerus*, *Megalonyx*) in the Hemphillian.

The faunal terminology is that of Tedford et al. (MS): "the term 'fauna' is used for stratigraphically as well as geographically diverse sam-

ples and the term 'local fauna' is thus brought into conformity with the definition of most authors ... a nearly contemporaneous assemblage derived from a limited geographic area."

No new names have been introduced, but the taxonomy conforms to more recent usage. Richard H. Tedford has furnished the taxonomy and notes on the Carnivora; Beryl E. Taylor has furnished the taxonomy and notes for the Tylopoda and Ruminantia. Marjory Coombs has enumerated the Sheep Creek and Olcott quarries that have yielded chalicotheres remains.

THE SHEEP CREEK FAUNA (LATE HEMINGFORDIAN), SHEEP CREEK FORMATION

CLASS REPTILIA

ORDER CHELONIA

FAMILY TESTUDINIDAE

Testudo (Hesperotestudo) angusticeps (Matthew, 1924a, p. 210) Williams, 1950, p. 25. (Type AMNH 6295 from Thomson Quarry.)

CLASS AVES

ORDER ACCIPITRIFORMES

FAMILY BUTEONIDAE

Hypomorphus enectus (Wetmore, 1923) Brod-korb, 1964, p. 267. (Type AMNH 6300, 1922 expedition, from Thomson Quarry.)

FAMILY ACCIPITRIDAE

Neophrontops vetustus Wetmore, 1943, p. 229. (Type HC 691 =AMNH obtained by Cook in 1938 from Thomson Quarry.)

ORDER GALLIFORMES

FAMILY PHASIANIDAE

Crytonyx cooki Wetmore, 1934, p. 30. (Type HC 647 =AMNH 8301, obtained by Cook in 1933. Fide Cook [MS], the specimen came from the "upper Sheep Creek beds, above heavy ash layer, western exposures." This is the *Aphelops* Draw area, figs. 2, 6E.)

ORDER RALLIFORMES

FAMILY ARAMIDAE

Aramornis longurio Wetmore, 1926, pp. 1-3. (Type AMNH 6292, collected by Thomson in 1923, from Thomson Quarry.)

ORDER PSITTACIFORMES

FAMILY PSITTACIDAE

Conuropsis fratercula Wetmore, 1926, pp. 3-5. (Type AMNH 6292a, collected by Thomson [MS.f] probably from Thomson Quarry. Wetmore, 1926, p. 3, stated: "[Horizon A] *Merychippus primus* zone, of the Sheep Creek beds.")

CLASS MAMMALIA

ORDER INSECTIVORA

FAMILY ERINACEIDAE

Brachyerix macrotis Matthew, 1933, in Matthew and Mook, 1933, p. 2, fig. 1. Rich and Rich, 1971, p. 15, refer a left ramus F:AM 76693, collected by Wilson in 1935 from Greenside Quarry, to *B. macrotis*.

ORDER RODENTIA

FAMILY MYLAGAULIDAE

Mesogaulus vetus (Matthew, 1924a, pp. 82-84). (Type AMNH 18905, collected by Thomson in 1921 from Thomson Quarry.)
Mesogaulus novellus (Matthew, 1924a, p. 84). (Type AMNH 18911, collected by Thomson in 1922 from Thomson quarry.)

ORDER CARNIVORA

FAMILY CANIDAE

Tomarctus optatus Matthew, 1924a, pp. 98-100, fig. 18. (Type AMNH 18916, collected by Thomson in 1922 from Thomson Quarry.)
Cynarctoides mustelinus (Matthew, 1932) Galbreath, 1956, pp. 374-375. (Type AMNH 20502, 1923 expedition from Thomson Quarry.)
Tomarctus cf. *confertus* (Matthew and Cook, 1909, p. 376). (AMNH 13859, 1908 expedition, exact site unknown.)

FAMILY AMPHICYONIDAE

Amphicyon idoneus Matthew, 1924a, p. 113, fig. 25. (Type AMNH 18912, 1922 expedition from Thomson Quarry.)
Amphicyon frendens Matthew, 1924a, pp. 111-113, fig. 26. (Type AMNH 18913, 1922 expedition from Thomson Quarry.)

FAMILY MUSTELIDAE

Brachypsalis matutinus Matthew, 1924a, pp. 133-134, figs. 32, 33. (Type AMNH 18921, 1922 expedition from Thomson Quarry.)
Sthenictis bellus Matthew, 1932, pp. 1, 2, fig. 1.

(Type AMNH 20501, 1923 expedition from Thomson Quarry.)

Dinogale siouxensis Cook and Macdonald, 1962, p. 564, fig. 3 (Type HC 679 =AMNH 81009 collected by Cook in 1937 from Thomson Quarry.)

Mionictis letifer Cook and Macdonald, 1962, p. 564, fig. 4. (Type HC 484 =AMNH 81006 collected by Cook in 1925 from *Pliohippus* Draw, middle part of Sheep Creek Formation.)

ORDER PERISSODACTYLA

FAMILY EQUIDAE

Parahippus sp. (Osborn, 1918, pp. 87-89). (A partial skull, mandible, and partial limbs, AMNH 14182, collected by Matthew in 1908 from 20-30 feet below the Sheep Creek Ash in *Merychippus* Draw. Osborn, 1918, referred this specimen to *Parahippus avus* [Marsh, 1874] from the Mascall Formation in Oregon, but the dentition of AMNH 14182 is worn beyond specific identification. AMNH 14182 resembles *Parahippus cognatus* in having a widely expanded, shallow preorbital fossa, but no malar fossa or scar. The extreme stage of wear of AMNH 14182 makes it impossible to see if the dentition had a cement covering, or if the exceptionally heavy, smooth enamel had crenulations like those of Marsh's type of *P. avus*. Matrix adhering to the specimen, AMNH 14182, is characteristic of the Sheep Creek sediments in *Merychippus* Draw.)

Archaeohippus penultimus Matthew, 1924a, pp. 158, 159. (The type, AMNH 18950, collected by Thomson, 1922, from Thomson Quarry. Twenty-seven specimens, including a partial skull and mandible, have been recognized in the Frick Collection. These occur in the lower and middle parts of the Sheep Creek Formation in Greenside, Long, Thomson, Hilltop, Ashbrook, Thistle, and Ravine quarries.) *Archaeohippus* has not been found in younger deposits in this area.

"Merychippus" primus (Osborn, 1918, pp. 17, 102-104), Matthew, 1924a, pp. 71, 162. (The type, AMNH 14187, consists of a P²-M³; the exact site is unknown. Matthew [1924a, p. 162] credited the source to "Lower Sheep Creek beds, Olcott Hill." The Sheep Creek is not present on Olcott Hill [present paper, p. 308] and Thomson [MS.a] did not list the specimen.) *"Merychippus" primus* is the dominant equid in the Sheep Creek Fauna. It

is unknown in the Lower Snake Creek Fauna, but occurs in large numbers in Thomson Quarry (more than 90 skulls and upper dentitions in the Frick Collection) and has also been found in Greenside, Thistle, and Hilltop quarries. *Pseudhipparion retrusum* and *P. gratus* are descendants of *"Merychippus" primus*. They do not appear in the Lower Snake Creek Fauna, but are present in large numbers in the Medial Miocene Valentine and Ash Hollow formations. They are rare in the Hemphillian.

Merychippus insignis tertius (Osborn, 1918, pp. 105-106). (The type, AMNH 14180, consists of a palate, mandible, and partial limbs collected by Thomson in 1908 from 41 feet below the Sheep Creek Ash in *Merychippus* Draw.)

Osborn placed this subspecies in *"Merychippus" isonesus*, but we believe that it is more closely allied with *Merychippus insignis* of the Lower Snake Creek Fauna.

"Merychippus" isonesus quintus (Osborn, 1918, pp. 107, 108). (The type, AMNH 14185, collected by Matthew in 1908 from 6-10 feet below the Sheep Creek Ash in *Merychippus* Draw.)

For an exhibition mount, the Museum attached the palate of the type of *"M." isonesus quintus* to a cast of the type of *Merychippus republicanus* Osborn, 1918, AMNH 8347. Specimens referable to *M. republicanus* have been found in the Valentine Formation in north-central Nebraska. The preorbital region of *M. isonesus* and *M. republicanus* are different: *"M." isonesus* has a narrow, compressed facial crest, a distinct malar fossa, and a deep lacrimal fossa, both of which are close to the orbit. The lacrimal fossa has a sharp posterior border broadly expanded anteriorly and confluent with the malar fossa. *Merychippus republicanus* has a fully inflated, well-rounded facial crest, no indication of a malar fossa or scar, and instead of a lacrimal fossa, has a shallow subnasal fossa with gently rounded borders well ahead of the orbit. The type of *"M." isonesus* is slightly larger than Osborn's variety of *"M." isonesus quintus*.

Merychippus sp. indet. (Osborn, 1918, p. 105). (The type, AMNH 14179, collected by Cook

in 1908 from 50 feet below the Sheep Creek Ash in *Merychippus* Draw.)

On the tenuous evidence of fragmentary teeth and postcranial elements that may represent more than one individual, Osborn, 1918, established the subspecies *Merychippus isonesus secundus*.

Genus and sp. indet. (Osborn, 1918, p. 107).

(The type, AMNH 14184, collected by Matthew in 1908 from 6 to 10 feet below the Sheep Creek Ash in *Merychippus* Draw.)

On the basis of limbs alone Osborn, 1918, erected the new subspecies, *Merychippus isonesus quartus*.

FAMILY CHALICOTHERIIDAE

Margery Coombs (personal commun., 1973) stated, "Chalicotheres are known from the following localities within the Sheep Creek Formation: Greenside, Hilltop, East Ravine, Ravine, and Thomson quarries; *Plihippus* Draw, 15 feet below Rhino Quarry, Rhino and Buck quarries, [and] Sheep Creek formation in *Aphelops* Draw. Although there are specimens from both the lower and middle parts of the Sheep Creek Formation, all evidence suggests that a single chalicotheres species is represented. This species, a new one soon to be named, is clearly referable to *Moropus* and is most closely related to *Moropus matthewi* Holland and Peterson, 1913, from northeastern Colorado."

ORDER ARTIODACTYLA

FAMILY TAYASSUIDAE

Cynorca occidentale Woodburne, 1969, pp. 309-312. (F:AM 73448, referred specimen collected by Wilson in 1937 from Ravine Quarry.)

Cf. *Desmathyus*, Matthew, 1924a. (AMNH 18952, referred specimen, 1922 expedition, from Thomson Quarry.)

FAMILY MERYCOIDODONTIDAE

Brachycrus wilsoni Schultz and Falkenbach, 1940, pp. 242-243, figs. 1, 7, 11. (Type F:AM 34202 collected by Wilson and Long in 1936 from Greenside Quarry.)

Brachycrus wilsoni longensis Schultz and Falkenbach, 1940, p. 247, fig. 9. (Type F:AM 33574

collected by Wilson and Long in 1934 from Long Quarry.)

Merychys (Metoreodon) relictus taylori Schultz and Falkenbach, 1947, p. 241, figs. 1, 8 (Type F:AM 34319 collected by Wilson and Long in 1936 from Long Quarry.)

SUBORDER TYLOPODA

FAMILY CAMELIDAE

Aepycamelus priscus (Matthew, 1924a, p. 187) Macdonald, 1956, p. 199. (Type AMNH 14189, 1908 expedition. Matthew, 1924, p. 187, stated that the type came from the "Sheep Creek beds, *Merychippus* Draw.")

Protolabis saxeus Matthew, 1924a, pp. 190, 191. (Type AMNH 18960, 1922 expedition from Thomson Quarry.)

Miolabis tenuis Matthew, 1924a, pp. 191-193, fig. 56. (Type AMNH 18965, 1922 expedition from Thomson Quarry.)

SUBORDER RUMINANTIA

FAMILY CERVIDAE

Blastomeryx medius Matthew, 1924a, p. 195, fig. 57. (Type AMNH 18955, 1922 expedition, from Thomson Quarry.)

Sinclairomeryx riparius (Matthew, 1924a, p. 197, fig. 58) Frick, 1937, p. 165. (Type AMNH 18956, 1922 expedition, from Thomson Quarry.)

Frick (1937, p. 164) described *Sinclairomeryx sinclairi*, genotypic species, based on a skull with horns and dentition, and then questionably referred *Blastomeryx (Dyseomeryx) riparius* Matthew (1924a) to *Sinclairomeryx* on the grounds that, although "the premolars of the type maxilla of (?) *S. riparius* seem to be smaller-proportioned than in the type cranium of *S. sinclairi*, the latter eventually may prove to represent the same form as *S. riparius*, which would then take precedence." Additional material collected since 1937 shows that the dentitions of *S. riparius* and *S. sinclairi* appear to represent one species, in which case the name *S. riparius* takes precedence.

Subdromomeryx scotti Frick, 1937, p. 123, fig. 14B. (Type F:AM 33758 collected by Wilson in 1936 from Greenside Quarry.) *Subdromomeryx wilsoni* Frick, 1937, p. 126, fig. 14B = *Subdromomeryx scotti*.

The type of *S. wilsoni* is a partial skull without

dentition, F:AM 33800, and was also collected by Wilson in 1936. Frick stated that it differed from *S. scotti* in: "The small size of the cranium and the anteroposterior and transverse slenderness of the horn-pedicle bases . . ." Considering the known variation in the size of dromomerycid horns and the unknown stage of maturity because of the absence of dentition, the type of *S. wilsoni* is more likely a smaller individual, or a not fully mature individual that may represent an intermediate stage of horn development between that of the type of *S. scotti* and the adolescent referred skull, F:AM 33757, in Frick, 1937, fig. 14B.

Bouromeryx submilleri Frick, 1937, p. 131. (Type F:AM 33729 collected by Wilson in 1936 from Greenside Quarry.)

Bouromeryx milleri Frick, 1937, p. 130, figs. 5, 7. (Type AMNH 21533 collected by Paul Miller in 1925 from the Sheep Creek beds in *Aphelops* Draw.)

FAMILY ANTILOCAPRIDAE

Merycodus sabulonis (Matthew and Cook, 1909b, p. 411, fig. 24): Skinner and Taylor, 1967, pp. 40-41, stated: "Subsequent Frick collections of *Merycodus sabulonis*, referred, [come] from both Sheep Creek and Lower Snake Creek beds." Specimens (unpublished) have been collected in Greenside and Long quarries. (See the Lower Snake Creek Fauna, present paper, p. 349.)

Cosoryx (Paracosoryx) wilsoni Frick, 1937, p. 351, fig. 37. (Type F:AM 32470 collected by Wilson in 1935 from Long Quarry.)

THE LOWER SNAKE CREEK FAUNA (EARLY BARSTOVIAN), OLCOTT FORMATION

Figures 2, 4A, 4B, 5D, 15

CLASS AMPHIBIA

ORDER URODELA

FAMILY CRYPTOBRANCHIDEA

Plicagnathus matthewi Cook, 1917, Abstr., Geol. Soc. Amer. Bull., vol. 28, p. 213. (Type HC 326 =AMNH 8303, collected by Cook in 1915 from the *Mesoceras thomsoni* locality in West Sinclair Draw.)

CLASS REPTILIA

ORDER CROCODYLIA

FAMILY CROCODYLIDAE

Alligator thomsoni Mook, 1923, pp. 1-13, 5 figs. (Type AMNH 1736, collected by Thomson in July, 1921, from Trojan Quarry, East Sinclair Draw.)

ORDER CHELONIA

FAMILY TRIONYCHIDAE

Platypeltis miocaenus Matthew, 1924a, p. 207, fig. 62. (Type AMNH 6298, 1921 expedition, from Trojan Quarry.)

FAMILY TESTUDINIDAE

Chelydrops stricta Matthew, 1924a, pp. 208-210, fig. 63. (Type AMNH 6297, 1921 expedition, from East Surface Quarry, East Sinclair Draw.)

CLASS AVES

ORDER ANSERIFORMES

FAMILY ANATIDAE

Anserinae gen. and sp. indeterminate Wetmore, 1923, p. 489. (AMNH 1764, collected by Thomson in 1921 from Trojan Quarry.)

ORDER ACCIPITRIFORMES

FAMILY BUTEONIDAE

Buteo typhoius Wetmore, 1923, pp. 489-492. (Type AMNH 1754, collected by Whitford and Stoll, 1916; exact site unknown, Sinclair Draw area.)

Buteo contortus (Wetmore, 1923, pp. 492-497) Brodkorb, 1964, p. 266. (Type AMNH 1758, collected by Whitford and Stoll in 1916, probably from the Sinclair Draw area, but exact site unknown.)

CLASS MAMMALIA

ORDER INSECTIVORA

FAMILY ERINACEIDAE

Brachyerix incertis (Matthew, 1924a) Rich and Rich, 1971. (Type AMNH 18891, collected by Thomson in 1921 from Trojan Quarry.)

ORDER RODENTIA

FAMILY HETEROMYIDAE

Peridiomys rusticus Matthew, 1924a, p. 85, fig. 9. (Type AMNH 18894, 1921 expedition, from Far Surface Quarry.)

FAMILY MYLAGAULIDAE

Mylagaulus laevis Matthew, 1902, p. 298; Matthew, 1924a, pp. 78-82. (The type is from the Pawnee Creek Formation in Colorado. A referred specimen, AMNH 17576—wrongly cited in Matthew's text as AMNH 17256—collected by Thomson in 1921 from Sinclair Draw, exact site unknown. AMNH 18896 was collected by Thomson in 1921 from Far Surface Quarry.)

FAMILY CASTORIDAE

Monosaulax curtis (Matthew and Cook, 1909, p. 381, fig. 9) Stirton, 1935, pp. 420, 421, figs. 74-75. (Type AMNH 13871, 1908 expedition, site unknown. Stirton, 1935, p. 420, reported only that the type and a lower jaw, AMNH 17575, came from Sinclair Draw.)

Monosaulax pansus (Cope, 1874b) Stirton, 1935, p. 416, figs. 66-69. (Type USNM 1097 is from the Santa Fe marls, New Mexico. Referred specimens from Sinclair Draw, 1916 expedition, exact site unknown: AMNH 17216, 17216a, 18990, 18991, 18992).

Amblycastor fluminis Matthew, 1918, pp. 197-199, fig. 7. (Type AMNH 17213, collected by Whitford and Stoll, 1916, from unknown site. Stirton, 1935, p. 411, cited these specimens: AMNH 18908 from East Surface Quarry, AMNH 22068 from Grass Roots Quarry, and AMNH 22393 from Ashbrook Pasture.)

FAMILY CRICETIDAE

Poamys rivicola Matthew, 1924a, p. 86, fig. 10. (Type AMNH 18892, 1921 expedition, from Far Surface Quarry. This type is lost.)

ORDER CARNIVORA

FAMILY CANIDAE

Tomarctus hippophagus (Matthew and Cook, 1909b, pp. 373-375, fig. 4), Matthew, 1924a, p. 91. (Matthew's synonymy of *Tephrocyon hippophagus* with *Tomarctus brevirostris* should be withheld pending analysis of larger samples from the Olcott and Pawnee Creek formations. Type AMNH 13836, 1908 expedition, is probably from East Sinclair Draw, although the exact site is not known. Referred specimens, 1921 expedition: AMNH 18242 from Camel Quarry, or from Far Surface Quarry; AMNH 18243, 18244, from Trojan Quarry.)

Euoplocyon praedator Matthew, 1924a, pp. 103-104. (Type AMNH 18261, 1921 expedition, from Trojan Quarry.)

Tomarctus confertus (Matthew, 1918, pp. 188-189, fig. 1) Matthew, 1924a, p. 65. (Type AMNH 17203, 1916 expedition. Referred specimen, AMNH 18253, 1921 expedition, from Far Surface Quarry.)

FAMILY AMPHICYONIDAE

Amphicyon sinapius Matthew, 1902. (Type from Pawnee Creek, Colorado. Referred specimens, 1921 expedition: AMNH 18257, 18258, 18259 from East Surface Quarry, and AMNH 18260 from Far Surface Quarry or Camel Quarry.)

Amphicyon amnicola Matthew and Cook, 1909b = *Amphicyon sinapius* Matthew, 1902. (Type AMNH 13846, 1908 expedition. No data.)

Amphicyon ingens Matthew, 1924a, p. 111, fig. 24. (Type AMNH 18272, 1921 expedition. Probably from the Olcott Formation in the Sinclair Draw area.)

Pliocyon medius Matthew, 1918, pp. 190-194, figs. 2, 3. (Type AMNH 17207, skull collected by Whitford and Stoll, 1916, for which no data has been found. F:AM 54319, mandible collected by Wilson in 1933 from East Surface Quarry, exactly matches the anomalous wear of the dentition of the type.)

FAMILY PROCYONIDAE

Bassariscus antiquus Matthew and Cook, 1909b, p. 377, fig. 6. (Type AMNH 13860, 1908 expedition, exact site unknown.)

FAMILY MUSTELIDAE

Brachypsalis obliquidens Sinclair, 1915, pp. 79,

- 80, fig. 3. (Type PU 12070, 1914 Princeton expedition, from locality 1000C, fig. 15.)
- Plionictis ogygia* (Matthew, 1901). (The type of *Martes glareae* Sinclair, 1915 [PU 12071] from Princeton Locality 1000C was referred to *P. ogygia* by Webb, 1969, p. 68. Cook and Macdonald, 1962, p. 566, referred HC 324 = AMNH 81040, a lower jaw from the *Mesoceras thomsoni* locality, to *Plionictis* cf. *glareae*, which appears to be a species of *Bassariscus*.)
- Sthenictis dolichops* Matthew, 1924a, p. 135, fig. 34. (Type AMNH 18264, 1921 expedition, from Trojan Quarry.)
- Leptarctus primus* Leidy, 1857: Matthew, 1924a, pp. 139-146, figs. 37-38. (Referred specimens, 1921 expedition: AMNH 18241 from Trojan Quarry, AMNH 18270 from Far Surface Quarry.)
- Mionictis incertus* Matthew, 1924a, pp. 136, 137, fig. 36. (Type AMNH 18263, 1921 expedition, from East Surface Quarry.)
- Mionictis elegans* Matthew, 1924a, p. 137. (Type AMNH 18267, 1921 expedition, from Far Surface Quarry.)
- Brachypsaloides modicus* (Matthew, 1918, p. 195) Webb, 1969, p. 58. (Type AMNH 17209 was collected on the 1916 expedition for which no data was found. Matthew, 1924a, p. 65, placed *B. modicus* in his "*M. paniensis* Zone" = Lower Snake Creek Fauna.)
- Plionictis parviloba* Matthew, 1924a, pp. 135, 136, fig. 35. (Type AMNH 17208 collected by the 1916 expedition, site unknown. Matthew, 1924a, p. 65, placed *P. parviloba* in his "*M. paniensis* Zone.")

FAMILY FELIDAE

- Pseudaelurus intrepidus sinclairi* Matthew, 1918, p. 196, fig. 6. (Type AMNH 17212 collected by the 1916 expedition from the Sinclair Draw area, exact site unknown.)
- Pseudaelurus aeluroides* Macdonald, 1954, pp. 67-69, fig. 1. (Type SDSM 5248, northeast rim of Sinclair Draw.)

ORDER PERISSODACTYLA

FAMILY EQUIDAE

- Hypohippus pertinax* Matthew, 1918, p. 211. (Type AMNH 17232, collected by Whitford and Stoll in 1916, from an unknown site. Specimens referable to *H. pertinax* have been collected from East Surface and Jenkins quarries. In the Frick Collection only 10 specimens of

H. pertinax are recognized; it is believed to be one of the rare equid species.)

- Desmatippus integer* (Matthew, 1924a, pp. 154-158). (The type, AMNH 81094 = HC 310, collected by Cook [MS] at the "*Hesperopithecus*" site on Olcott Hill. All other specimens referable to this group, however, are from the Lower Snake Creek Fauna. Paratypes AMNH 17567, 17568, lower jaws, collected in 1918 in Sinclair Draw in the Olcott Formation. In the Frick Collection, most examples of *D. integer* are from Echo and Jenkins quarries, a few others are from West and New Surface, Version, and *Prosynthetoceras* quarries.)
- Merychippus insignis* Leidy, 1857, p. 311. (The type, ANSP 11276, is an immature maxilla with dP^{2-3} , collected by F. V. Hayden from the Bijou Hills, South Dakota, in 1856.)

The type of *M. insignis* (ANSP 11276) was duplicated in a series of immature to mature specimens from Echo Quarry, thus establishing not only the dental characters, but the facial characters as well, of the genotypic species, *M. insignis*. Skinner and Taylor (1967, pp. 18-35, figs. 5-8) referred nine skulls and 56 maxillaries from the Lower Snake Creek Fauna (Echo Quarry) to *M. insignis*. The skulls range from youth to old age, male and female.

Matthew (1924a, pp. 159-162) referred the bulk of his equid material to *Merychippus paniensis*. The holotype, which consists of two isolated teeth (AMNH 8249), came from the Pawnee Buttes in northeastern Colorado; there is no stratigraphic record. To illustrate his concept of *M. paniensis*, Matthew (1924a) cited two skulls (AMNH 18297 and 18299), both of which are referable to *Merychippus insignis* on the basis of dental and facial patterns. We treat *M. paniensis* as a synonym of *M. insignis*.

FAMILY CHALICOTHERIIDAE

Margery Coombs (personal commun., 1973) stated, "Barstovian chalicotheres are known from Echo and *Prosynthetoceras* quarries. This species, although definitely referable to *Moropus*, is not derived from the chalicothere known from the Sheep Creek Formation. Rather it is very close to the Barstovian species *Moropus merriami* Holland and Peterson, 1914, from the Virgin Valley Formation of Nevada. The Lower Snake Creek species show affinities to a species found in the

Runningwater Formation in Dawes County,
Nebraska."

FAMILY RHINOCEROTIDAE

Teleoceras (Mesoceras) thomsoni Cook, 1930, p. 49, pls. 5-7. (Type HC 495 =AMNH 82592 collected by H. J. and J. C. Cook in 1925 from the *Mesoceras thomsoni* locality, West Sinclair Draw.)

ORDER ARTIODACTYLA

FAMILY TAYASSUIDAE

Dyseohyus stirtoni Woodburne, 1969, pp. 325-333, referred specimens from Jenkins Quarry: F:AM 73682, 73683, collected by Wilson in 1940 and F:AM 73684, 73685 collected by Skinner in 1941, 1942. Skinner also collected F:AM 73686 from Echo Quarry and F:AM 73687 from *Prosynthetoceras* Quarry in 1946.

FAMILY MERYCOIDODONTIDAE

Brachycrus siouense (Sinclair, 1915, pp. 86-87, fig. 11) Schultz and Falkenbach, 1940, pp. 232-241. (Type PU 12057 from Princeton's 1914 Locality 1000C. Schultz and Falkenbach [1940, p. 233] referred more than 500 specimens to *B. siouense* that were collected from quarries in East and West Sinclair draws and in Antelope and Ranch House draws. Whitford and Barner, on the 1914 Princeton expedition, probably collected the type of *B. siouense* in either the East or the West Sinclair Draw.)

Ticholeptus hypsodus Loomis, 1924, pp. 35-36, fig. 25. (Type AMNH 14057, 1908 expedition, from unknown site. Schultz and Falkenbach, 1941, p. 76, based some of their revised generic characters on F:AM 43043 [collected by Wilson and Long in 1940] from Jenkins Quarry, and on F:AM 43073 [collected by Wilson and Long in 1939] from East Surface Quarry. Schultz and Falkenbach, 1941, referred 90 specimens to *T. hypsodus* from quarries in East and West Sinclair draws and in Antelope and Ranch House draws. The type probably came from East or West Sinclair Draw.)

Mediochoerus blicki Schultz and Falkenbach, 1941, pp. 93-94, figs. 1, 16, 17. (Type F:AM 43172 collected by Wilson and Long in 1938 from New Surface Quarry in East Sinclair Draw.)

SUBORDER TYLOPODA

FAMILY PROTOCERATIDAE

Prosynthetoceras (Lambdoceras) siouxensis Frick, 1937, p. 60; Patton and Taylor, 1971, p. 189. (Type AMNH 17344, 1916 expedition, site unknown. Referred specimens in the Frick Collection have been taken from *Prosynthetoceras*, Echo, West Sand, and Version quarries, all of which are in the Olcott Formation.)

Matthew (1918, fig. 20) referred the type of *P. (L.) siouxensis* to *Cranioceras unicornis*, incorrectly citing AMNH 17144 as the number.

FAMILY CAMELIDAE

Miolabis princetonianus (Sinclair, 1915, p. 87, figs. 12, 13) Frick and Taylor, 1971, p. 4. (Type PU 12053, 1914 expedition, Sinclair Draw area.)

Plauchenia singularis Matthew, 1918, p. 216, fig. 16. (Type AMNH 17329, 1916 expedition. Site unknown.)

Aepycamelus procerus (Matthew and Cook, 1909b, pp. 402, figs. 19, 20) Macdonald, 1956, p. 198. (Type, AMNH 14070, 1908 expedition. Thomson [MS.a] gave the locality as "Quarry 2," which is not the same as Thomson's 1918 Quarry 2 in *Aphelops* Draw, the site of part of the *Aphelops* Draw Fauna. Matthew, 1924a, p. 186, stated: "Re-examination in 1922 of the point where this specimen was excavated shows that it is from the *M. [Merychippus] paniensis* zone in Sinclair draw.") The type is typical of *Aepycamelus* specimens from the Olcott Formation and unlike the rare specimens of *Aepycamelus* from the Snake Creek Formation. *Aepycamelus* species from the Clarendonian or later are easily recognized and distinguished from the Barstovian species by their larger size, longer proportioned muzzle, loss of I_1^2 and P_2^2 , and proportionally longer metapodials. There is no doubt that the type of *A. procerus* is from the Olcott Formation.

Procamelus leptocolon (Matthew, 1924a, p. 187. Matthew's [1901, p. 427, footnote b] "*Alticamelus*" *leptocolon* from northeastern Colorado was based on a specimen referred to *Procamelus robustus* Leidy, 1858. AMNH 18350 and 18869, 1921 expedition, came from Trojan Quarry, East Sinclair Draw.) The type (AMNH 9116) is from Pawnee Creek, Logan County, Colorado.

Matthew (1901, p. 427) referred to *Procamelus robustus* two immature jaws with associated limb parts (AMNH 9116) and figured limb elements (AMNH 9114 and 9117). Matthew (1924a, p. 187) designated "portions of the lower jaws and feet," AMNH 9115, as the type of *Alticamelus leptocolon*. This specimen (AMNH 9115) consists only of a carpus and partial foot and Matthew's description of it is the originally referred AMNH 9116 that Matthew labeled "cotype." The type, AMNH 9116, consists of right and left partial jaws with dP_2-M_2 and broken limb elements, including an incomplete metacarpus. Unlike *Aepycamelus* the metacarpus is relatively short and robust, similar in proportion to *Protolabis* and *Procamelus*. The deciduous premolars are larger than in *Protolabis*. The molars are taller crowned than those of *Aepycamelus* and comparable with specimens referable to *Procamelus* from the Valentine Formation in Nebraska. On the basis of the relatively tall-crowned molars and the short-proportioned metacarpus, the type of *leptocolon* is placed in the genus *Procamelus*.

SUBORDER RUMINANTIA

FAMILY CERVIDAE

Blastomeryx elegans Matthew and Cook, 1909b, p. 410; Frick, 1937, p. 237. (Type AMNH 14101, 1908 expedition; exact site unknown. Frick, 1937, p. 237, questionably referred to this species specimens from Echo Quarry in the Olcott Formation.)

Drepanomeryx falciformis Sinclair, 1915, p. 90, figs. 14, 15. (Type PU 12072, 1914 Princeton expedition, from West Sinclair Draw, but exact site unknown.)

Dromomeryx whitfordi Sinclair, 1915, pp. 94-95, fig. 17. (Type PU 12054 1914 expedition, West Sinclair Draw, but exact site unknown.)

Rakomeryx sinclairi (Matthew, 1918, p. 218, fig. 17). (Type AMNH 17338, 1916 expedition, from unknown site, but probably in the Sinclair Draw area.) Because of dental similarity to *Cranioceras*, Frick, 1937, p. 83, placed *Cervavus sinclairi* from the Olcott Formation in synonymy with *Cranioceras unicornis*. Additional material shows that *C. unicornis* does not occur in the Olcott Formation. The dentition of the type of *Cervavus sinclairi* is comparable to *Rakomeryx* species from Early Barstovian deposits in California.

Bouromeryx parvus (Cook, 1922b, p. 13, fig., p. 21) Frick, 1937, p. 131. (Type HC 295 =AMNH 81018, collected by Cook, 1914. No exact site is given, but the type is matched in the Lower Snake Creek Fauna. Frick questionably referred Cook's type of *Dromomeryx parvus* to *Bouromeryx*, and named another species, *Bouromeryx nebrascensis* from the Lower Snake Creek Fauna. The type of both *B. parvus* and *B. nebrascensis* are lower jaws, and the measurements of dentitions of *Bouromeryx* collected from the Olcott Formation since 1937 bracket the measurements of both types. Only one species, *B. parvus*, having priority, is thought to be represented.)

FAMILY ANTILOCAPRIDAE

Merycodus sabulonis Matthew and Cook, 1909b, p. 411, fig. 24; Skinner and Taylor, 1967, p. 43, fig. 11. (Type AMNH 14109, 1908 expedition, site unknown, but specimens similar to the type are found in the Lower Snake Creek Fauna, e.g., F:AM 51259 from New Surface Quarry.)

THE FAUNAS OF THE SNAKE CREEK FORMATION

THE LOCAL FAUNA (EARLY CLARENDONIAN), MURPHY MEMBER

CLASS REPTILIA

ORDER CHELONIA

FAMILY TESTUDINIDAE

Testudo sp. (Shell fragments, F:AM 6983, collected by Skinner in 1972 from Olcott Hill near the top of the Murphy Member and close by the iron rod that marks the site of "Hes-

peropithecus" haroldcookii. Cook [MS] often referred to this *Testudo* specimen.)

CLASS MAMMALIA

ORDER LAGOMORPHA

FAMILY LEPORIDAE

Hypolagus cf. *vetus* (teeth and bone fragments, F:AM 94077, in what may have been a coprolite, collected by Skinner in 1972 from the

slump blocks in East *Pliohippus* Draw. Mary Dawson [personal commun., 1973] stated: "*Hypolagus vetus* is known from the Clarendonian and Hemphillian. This example is rather advanced in the crenulations in the folds on the upper teeth, and the P_3 looks normal for *Hypolagus*. I would estimate that, morphologically, it could be younger than Clarendonian, but not older."

ORDER ARTIODACTYLA

SUBORDER SUIFORMES

FAMILY TAYASSUIDAE

Prosthennops sp. (HC 355 =AMNH 95571, right lower jaw with P_2-M_3 and associated canine, collected by Cook in 1916 in *Pliohippus* Draw. Cook [MS] stated that the specimen was "found in place, weathering out of one of the large, 'tumbled down masses' of Sheep Creek matrix, that have the coarse Snake Creek sand-gravel filling *between them*." Note Cook's allocation of a Sheep Creek age for the slump blocks. Twenty years later (in 1937) Cook's (MS) description of what were probably the same beds at the same place, for two tayassuid jaws (HC 677 =AMNH 95572 and HC 678 =AMNH 95573 discussed below) was "Upper Sheep Creek Beds. West head of *Pliohippus* Draw, typ. locality." Neither *Platygonus* nor *Prosthennops* are known from the Sheep Creek Fauna.

Michael O. Woodburne in a letter of November 30, 1973 stated, "based on non-reduced talonid of the last premolar and the sharply narrower second and third premolars . . . this specimen may be one of the *Prosthennops* group, probably about Clarendonian stage of evolution." Skinner has collected specimens in a similar stage of development as AMNH 95571 from the Cap Rock Member of the Ash Hollow Formation of north-central Nebraska. The Cap Rock, which is the lowest part of the Ash Hollow (*sensu* Skinner et al., 1968), produces an Early Clarendonian fauna.

Woodburne (personal commun.) thought that Cook's two other "tayassuids" (AMNH 95572, 95573) are also referable to either *Platygonus* or *Prosthennops* of equivalent Clarendonian age as AMNH 95571. Although Skinner has collected *Platygonus*-like dentitions from the uppermost

part of the Johnson Member in *Pliohippus* Draw [p. 313], none have been collected from the Murphy Member. On the basis of the present evidence, the occurrence of *Platygonus* in the Murphy Member is doubtful."

FAMILY MERYCOIDODONTIDAE

Ustatochoerus major (Leidy, 1858) Schultz and Falkenbach, 1941, p. 16. (Type USNM 439, partial right maxilla with P^3-M^2 , found by F. V. Hayden along the Niobrara River, but no additional locality data was given.)

In July, 1917, Cook found a right maxillary fragment of *U. major* (HC 1250 =AMNH 83545) with P^4-M^1 , and described (Cook, MS) its provenance on Olcott Hill as the "same locality as HC 425 [*Hesperopithecus cookii*], but in the underlying formation, at a spot 30 feet below." This puts the specimen in the Murphy Member 30 feet below the contact of the Murphy and Laucomer members of the Snake Creek Formation at this site. The characteristic reddish matrix of the Murphy Member adhered to the specimen. Cook (MS) was specific about the maxillary fragment (AMNH 83545) being found below the "*Hesperopithecus* pocket" (=Laucomer Member) near a *Longirostromeryx* jaw (HC 432 =AMNH 83442, present paper, p. 351). AMNH 83545 compares well with the type of *Ustatochoerus major*, USNM 439, and with *U. major* specimens from Frick faunal sites in the Ash Hollow Formation (e.g., Xmas-Kat quarries) (Late Clarendonian) on the north side of the Niobrara River in Cherry County, Nebraska.

SUBORDER TYLOPODA

FAMILY CAMELIDAE

Procamelus occidentalis Leidy, 1858, p. 23: Webb, 1965, pp. 37-40. (Type USNM 797, part of right ramus with P_4-M_3 slightly broken, and alveolus and partial root of P_3 , collected by F. V. Hayden in 1857, along the Niobrara River from an unknown site.)

A maxilla fragment with M^1-M^2 (F:AM 40663) collected by Skinner in 1972 from the slump blocks (Murphy Member) in East *Pliohippus* Draw. F:AM 40663 compares well with a maxilla, F:AM 37684, from above the Cap Rock Member in the Ash Hollow Formation (Late Clar-

endonian) in Cherry County, Nebraska. F:AM 40663 is slightly smaller than F:AM 37684, but the mesostyles of the two specimens are equally developed. A skull and mandible (F:AM 37657) also from above the Cap Rock Member in the Ash Hollow Formation along Bear Creek, Cherry County, Nebraska, has molars of about the same size as those of the Murphy Member specimen (F:AM 40663).

In June, 1975, Thomas F. Lamb collected a left ramus with P_2-M_2 , also from the slump blocks in East *Pliohippus* Draw, that can only be assigned to *P. occidentalis*.

SUBORDER RUMINANTIA

FAMILY CERVIDAE

Longirostromeryx wellsi (Matthew, 1904)
Frick, 1937

Longirostromeryx serpentis Frick, 1937, p. 232.

Type. AMNH 9823, left ramus with P_3-M_3 collected by H. F. Wells in 1902 near the Rosebud Agency, South Dakota.

Distribution. Deposits of Clarendonian age in the valley of the Little White River, South Dakota, and in Sioux County, Nebraska.

Diagnosis. See Matthew, 1904a, pp. 125, 126, fig. 18.

Referred Material. From the Murphy Member: Partial left ramus with P_4-M_3 (HC 432 = AMNH 83442) collected by Cook (MS) in July, 1917, "a few yards" from a maxilla of *Ustatochoerus major* (AMNH 83545); see locality data, page 310. Skinner collected in 1972 a right ramus with P_2-P_3 roots, P_4 erupting, M_1-M_3 (F:AM 51466),

with an anomalous lobe on M_3 , from the slump blocks in East *Pliohippus* Draw. From the Laucomer Member: Left ramus with symphysis and P_2-M_2 (AMNH 22029) collected by Thomson in 1926 from Kilpatrick Quarry on Olcott Hill. (This is Frick's type of *Longirostromeryx serpentis*.)

Remarks. The type of *Longirostromeryx wellsi* (AMNH 9823) from near the Rosebud Agency in South Dakota lacks a symphysis, whereas the symphysis of *L. serpentis* type (AMNH 22029) from the Laucomer Member in Sioux County (Kilpatrick Quarry, Olcott Hill) is nearly complete. The reduction in size of the premolars of *L. wellsi* (AMNH 9823) equals that of *L. serpentis* (AMNH 22029) and the dental characters and overall size are compatible also. The Murphy Member rami (AMNH 83442 and F:AM 51466) are also similar to the type of *L. wellsi* (AMNH 9823) in degree of premolar reduction, size and dental characters.

The exact discovery site of the type of *L. wellsi* (AMNH 9823) is unknown, but other Clarendonian fossils, not yet reported, have been found near the Rosebud Agency, South Dakota. In 1935 Skinner collected a skull and some postcranial elements (F:AM 70137) of *Pseudhipparion gratum*, known only from Clarendonian deposits that overlie the Early Arikareean Rosebud Formation at its type locality southeast of the Rosebud Agency Buildings. *Pseudhipparion gratum* (F:AM 70137) was collected at an elevation of 2860 feet on the section, 140 feet above the contact of the Rosebud-Pliocene undifferentiated (see Skinner, Skinner, and Gooris, 1968, fig. 6, pp. 394-395).

THE SNAKE CREEK FAUNA (LATE CLARENDONIAN), LAUCOMER MEMBER

THE TYPE FAUNA OF THE SNAKE CREEK FORMATION

CLASS AVES

ORDER GALLIFORMES

FAMILY CRACIDAE

Boreortalis phengitis (Wetmore, 1923, pp. 487-489) Brodkorb, 1964, p. 305. (Type HC

426 = AMNH 83000, from the "*Hesperopithecus*" site, Olcott Hill, fig. 4A.)

ORDER RALLIFORMES

FAMILY GRUIDAE

Grus ?canadensis, Wetmore, 1928, p. 1 (AMNH

6620, collected by Thomson in 1926 from Kilpatrick Quarry.)

CLASS MAMMALIA

ORDER RODENTIA

FAMILY CASTORIDAE

Eucastor cf. *tortus* Leidy, 1858: Stirton, 1935, pp. 429-431. (AMNH 22046, 22390, collected by Thomson in 1925 from Kilpatrick Quarry; AMNH 21467 from Olcott Hill.)

In a footnote to this assignment Stirton noted that the "Pliocene fossils on Olcott Hill [Laucomer Member, Late Clarendonian] . . . are older than those from *Aphelops* and *Pliohippus* draws." *Aphelops* and *Pliohippus* draws contain Johnson Member deposits of Hemphillian age.

Monosaulax pansus (Cope, 1874b) Stirton, 1935, p. 416. (Type USNM 1097 from the Santa Fe marls, New Mexico. Referred specimens HC 351 =AMNH 81072 and HC 352 =AMNH 81073 from the Laucomer Member on Olcott Hill.)

ORDER EDENTATA

FAMILY MEGALONYCHIDAE

Megalonychidae, Sinclair, 1915, p. 83; Hirschfeld and Webb, 1968, pp. 238, 279. (A navicular, PU 12079, was collected in 1914 by the Princeton expedition at Locality 1000C =Olcott Hill, Laucomer Member.)

This sloth bone is another of the enigmatic "occurrences" in the Snake Creek Formation that seem more related to human than fluvial transport. No pre-Hemphillian record of the *Xenarthra* are known anywhere in North America to date and we believe this small bone may have been incorrectly labeled in the days when the Johnson and Laucomer members were considered parts of a single depositional cycle.

ORDER CARNIVORA

FAMILY CANIDAE

Aelurodon mortifer (Cook, 1914, pp. 49, 50, pls. 1-3). (Type HC 270 =AMNH 81004, left ramus with complete dentition except for incisors and M₃, collected by Cook on May 14, 1914.)

Cook's locality data is open to some question. His catalogue for the type of *Aelurodon mortifer* (AMNH 81004) reads: "Exact location is shown on Photo of 'Snake Creek Beds,' published in Osborn's 1910 'Age of Mammals.'" The photograph (fig. 162) is of East Sinclair Draw. On May 31, 1914, Cook collected a colt jaw (HC 279 =AMNH 82053) from the "same loc. as HC 270." This specimen, which is referable to "*Hipparion*" *occidentale*, has the same fossilization as the type of *A. mortifer* and other fossils taken from the Laucomer Member on Olcott Hill. On the same day Cook also collected a carnivore jaw, *Tephrocyon hippophagus*, from "3/4 mile S.E. of spot where HC 270 was found." Cook (MS) sometimes gave incorrect directions and mileages, however. "Three quarters of a mile southeast" of Olcott Hill would be beyond both East and West Sinclair draws where no fossils have ever been found. Cook's reference to the photograph published in Osborn (1910) may have been to the label, "Snake Creek Beds," rather than to the specific site. Cook realized that the beds on Olcott Hill and those in East Sinclair Draw (or West Sinclair Draw) were temporally different but did not indicate, in publications, at least, that they were lithologically different. By this rationale the provenance for the type of *Aelurodon mortifer* (AMNH 81004) is assumed to have been from the Laucomer Member on Olcott Hill.

Cook (1930, p. 50) gave still another discovery site for the type of *Aelurodon mortifer*: "The specimen *Mesoceras thomsoni* was found in the lowest coarse sand and gravel bed of the Snake Creek beds . . . in the same horizon and spot as the types of *Tomarctus mortifer*, *Plicagnathus matthewi* . . ." This site is Cook's *Mesoceras thomsoni* Quarry in West Sinclair Draw (fig. 15). The large Frick Collection from East and West Sinclair draws, which was made under more rigid stratigraphic and geographic controls than either the Cook or AMNH collections from the same locale, has produced no specimens referable to *Aelurodon mortifer*.

Another *Aelurodon mortifer* specimen (F:AM 61562) was collected in 1942 by Skinner from the surface of West Jenkins Quarry in Sinclair Draw of Wilson (fig. 2), a site that neither Thomson nor Cook prospected. No specimens corre-

sponding to the type have been found *in situ* in the Olcott Formation. Large dogs, morphologically very close to *A. mortifer*, are common canids in the Laucomer Member of the Snake Creek Formation on Olcott Hill (i.e., AMNH 18262, 18262a, from Quarry C = Olcott Hill, and AMNH 22402a, b, from Kilpatrick Quarry). The jaw (F:AM 61562) collected by Skinner from West Jenkins Quarry is most likely reworked from deposits of a Snake Creek channel on the southwest side of Olcott Hill, now entirely removed.

Vanderhoof and Gregory (1940, pp. 146-147) synonymize *Aelurodon mortifer* with *A. haydeni*. Kitts (1957, p. 12) doubted this assignment and holds *A. mortifer* as distinct; a wise procedure pending analysis of larger collections now available.

FAMILY MUSTELIDAE

"Lutra" pristina (Matthew, 1904b). (Type AMNH 10811, a left ramus and symphysis with canine and P_3-M_1 collected by Gidley in 1903 in the "cañon of the Little White River." Fossils of Clarendonian age have been found in the valley of the Little White River [see *Longirostromeryx wellsii*, present paper, p. 351]. AMNH 18268 and 18922 collected by Thomson in 1921 and 1922 from Quarry C = "*Hesperopithecus*" site on Olcott Hill.)

Although originally (Matthew, 1904b, pp. 256-257) referred to the genus *Lutra* Brisson, 1762, this species has been included in the genus *Brachypsalis* Cope, 1890, by all later authors who have dealt with it. The most recent review (Webb, 1969) based a revised generic diagnosis for *Brachypsalis* on "*L.*" *pristina* (and its presumed synonym *B. obliquidens* Sinclair, 1915) and a referred skull fragment (UCMP 33900) from the Clarendonian Minnechadusa Fauna of Cherry County, Nebraska. The damaged holotype (AMNH 8544) of the genotypic species, *Brachypsalis pachycephalis*, contributed little to this revision.

Comparison of the lower jaws of "*L.*" *pristina* and *B. obliquidens*, however, reveals considerable differences in the morphology of the lower teeth. "*Lutra*" *pristina* does resemble the otters in that the carnassial has a low trigonid and longer, broader and basined talonid, whereas *B. obli-*

quidens resembles other species of that genus (including *B. modicus*, the type of the genus *Brachypsaloides* Webb, 1969) in having a high-crowned trigonid, short talonid (no wider than the trigonid) dominated by the crested hypoconid. The premolars of *Brachypsalis* are massive, often crowded, and the P_3 has a prominent posterior cusp, whereas the premolars of "*L.*" *pristina* are small, narrow, not crowded, and lack posterior cusps. Clearly "*Lutra*" *pristina* should be separated from *Brachypsalis*. Retaining the generic name in quotation marks will serve to indicate the uncertain position of "*Lutra*" *pristina* within the Mustelidae pending review of the systematics of these and allied forms.

ORDER PROBOSCIDEA

FAMILY GOMPHOTHERIIDAE

Serridentinus nebrascensis Osborn, 1924, p. 4: 1936, pp. 427, 473. (Thomson collected AMNH 21459 and 21452, in 1925, from Kilpatrick Quarry.)

Rhynchotherium anguivialis Osborn, 1925, p. 13, fig. 11: 1936, pp. 491, 492. (Type AMNH 19250, collected by Thomson in 1923 from the "*Hesperopithecus*" site on Olcott Hill. AMNH 21453, 21454 from Kilpatrick Quarry.)

ORDER PERISSODACTYLA

FAMILY EQUIDAE

The *Hipparion affine* Zone of Matthew: Matthew (1924a, p. 174) applied the term "*Hipparion affine* zone" to his "Upper Snake Creek" Fauna in order to distinguish it from his *Merychippus paniensis* and "doubtfully distinct *Pliohippus leidyani*" life zones. The term, "*Hipparion affine* channel," was perpetuated in the field lists and letters of Thomson, Wilson, and Skinner, to separate the Snake Creek channel deposits from those of the Lower Snake Creek. Matthew's designation of a life zone predicated on the predominance of *H. affine* was not well founded in the light of later collections. *Neohipparion affine* is a rare species in the Snake Creek Fauna, whereas "*Hipparion*" *occidentale* is the most dominant of all equid species in the Snake Creek Formation. The name, *Hipparion affine*, has been so widely used as the characteristic fossil in the

Snake Creek Fauna that a brief history of the name and the type specimen is given here:

Neohipparion affine (Leidy, 1869, p. 286) Gidley, 1907, pp. 887, 888. (Type USNM 584, four upper molars of one individual collected in 1857 by F. V. Hayden. Leidy, 1869, cited "from the Niobrara River" as the type locality, and Gidley, 1907, p. 887, gave the type locality as "near Fort Niobrara, Nebraska." Fort Niobrara was not established until April 22, 1880, so Gidley's citation of a type locality was only a guess.)

The type locality of *Neohipparion affine* may have been Porcupine Butte, South Dakota. In his journal for October 11, 1857, Hayden (1863, p. 32) reported that after "Leaving Wounded Knee creek we begin to meet with indications of the Pliocene beds. . . . A conical hill, left after the erosion of the surface around . . . containing numerous fragments of shells and turtles, bones and teeth of *Hipparion*, &c." The "conical hill" can only be Porcupine Butte, for it is not only conical but it is the one landmark in a wide surrounding area. Rationale for the provenance of *N. affine* type as Porcupine Butte is also based on the fact that Hayden was at least 32 airline miles from the Niobrara River (estimated as +40 land miles) when he found the "*Hipparion*" teeth, and these are the only hipparion-like teeth that Hayden mentioned in his record of the 1857 trip. Hayden found the type of "*Hipparion*" *occidentale* two years earlier (1855).

A stratigraphic section of Porcupine Butte (Skinner, 1950 unpubl. notes) shows about 25 feet of Pliocene channel deposits and layers of ash and hard concretions making up the top of the butte (Cap Rock Member, Ash Hollow Formation). A mastodont tooth fragment was found in the base of the channel deposit.

Gidley (1907, pp. 868, 869) revised and broadened his type diagnosis of *Neohipparion* to include facial as well as dental and limb characters: "Enamel foldings of fossette borders comparatively simple; protocone comparatively large, and laterally compressed; lachrymal fossa shallow, borders not sharply defined; malar fossa shallow or wanting; lower border of mandibular rami deeply bowed . . ." On the basis of the skulls (AMNH 10584), which he referred to

"*Hipparion*" *lenticularis* (Cope, 1893), Gidley also gave a general diagnosis for *Hipparion*: "fossette borders complex [on molars]; protocone comparatively small, and more or less circular in cross-section; lachrymal fossa large and infolded into a well-defined pit posteriorly; malar fossa shallow or wanting." Broad as these characters are, they give the general characters of the two groups, *Neohipparion affine* and "*Hipparion*" *occidentale*. Gidley (1907) further observed that *Hipparion lenticularis* was especially hipparion-like in the facial region, similar to the Old World *Hipparion gracile*.

Matthew (1918, 1924a) and Osborn (1918, p. 173) discontinued the use of Gidley's (1903) genus *Neohipparion* for tridactyl equids with isolated protocones, and thereafter used *Hipparion* (*sensu lato*). The characters that Gidley gave to separate *Hipparion* from *Neohipparion* were also disregarded, although it will be noted that Gidley (1907) was the first to ignore his own distinctions. Whereas Gidley (1903) had placed all but four North American hipparions in his genus *Neohipparion*, Matthew (1924a, pp. 172, 173) recognized two main groups of *Hipparion*: the *H. gratum* group included *H. lenticulare* and *H. plicatile*, and the *H. occidentale* group included *H. affine*, *H. whitneyi*, and *H. sinclairi*. The rarity of specimens referable to *Neohipparion* and the lack of complete skulls of the "*Hipparion*" *occidentale* group during Matthew's time may have prompted him to abandon the use of *Neohipparion*. It is difficult to reconcile Matthew's (1924a, p. 174) observation that *affine* might be a synonym of *occidentale* with his persistent use of the *H. affine* zone.

Cormohipparion occidentale (Leidy, 1869, pp. 281-282) Skinner and MacFadden (In press). (Type cast AMNH 10794, four upper molars of one individual collected in 1855 by F. V. Hayden at an unknown point along the White River, South Dakota. See Skinner and Taylor, 1967, pp. 17, 18).

Skinner and MacFadden (In press) based their new genus of an hipparion-like equid on the "presence of a relatively well-developed and usually continuous anterior rim of the nasomaxillary preorbital fossa. . . . The type is *Cormohipparion occidentale* based on dental similarities

between Leidy's type and some of the referred material."

A nearly complete skull (F:AM 71887) from Olcott Quarry on Olcott Hill, is of a moderately small female with complete dentition except for the third incisors and a left canine; the third molar is erupting. Several hundred detached teeth of *C. occidentale* have also been collected from Olcott Quarry and other spots on Olcott Hill, as have a few lower jaws, partial maxillae and limbs, but no articulated skulls and jaws have been found. Most of the fossils were probably brought in by swiftly flowing streams.

ORDER ARTIODACTYLA

SUBORDER SUIFORMES

FAMILY TAYASSUIDAE

Prosthennops haroldcookii (Osborn, 1922, pp. 2-5, 3 figs.), Hay, 1930, p. 770. (Type HC 425 =AMNH 17770 collected by Cook in 1917 on Olcott Hill. An iron rod marks the "*Hesperopithecus*" site where this specimen was found.)

Matthew and Cook (1909b, p. 390) referred isolated tayassuid teeth to *Prosthennops*, remarking on their "startling resemblance to the teeth of Anthropoidea." They pointed out that because of the contemporaneity of early man and bovids in the middle Pleistocene of Europe, the unexpected first occurrence of a similar bovid

(i.e., *Neotragocerus improvisus*) in the Pliocene Snake Creek Formation substantially increased the chances of finding early man in the same horizon.

In July, 1917, Cook found what he believed was an anthropoid molar, and five years later he sent the specimen to Osborn. Osborn (1922) promptly used it as the basis for the description and publication of a new genus and species of anthropoid, "*Hesperopithecus*" *haroldcookii*. Further studies showed that the molar was not that of an anthropoid (present paper, p. 281). In a letter to Skinner (November 26, 1934) Osborn asked for suitable specimens with which to compare the type tooth of *Prosthennops haroldcookii*: "I would like to clear up this matter myself rather than have others do it," he wrote. Osborn died before he published a second opinion on his controversial species and the attention on Pliocene man drifted elsewhere.

INFRAORDER OREODONTA

FAMILY MERYCOIDODONTIDAE

Ustatochoerus profectus (Matthew and Cook, 1909b, pp. 394, 395, fig. 15.) Schultz and Falkenbach, 1941, pp. 10, 11. (Type AMNH 14055, 1908 expedition. Wilson and Long in 1936 collected F:AM 34346 and F:AM 43200 from Olcott Quarry. *Ustatochoerus profectus* has not been found in the Sheep Creek and Lower Snake Creek faunas.)

THE APHELOPS DRAW FAUNA (EARLY HEMPHILLIAN), JOHNSON MEMBER

CLASS AVES

ORDER ACCIPITRIFORMES

FAMILY BUTEONIDAE

Buteo conterminus (Wetmore, 1923, pp. 497-499) Brodkorb, 1964, p. 266. (Type PU 12156, 1914 expedition, from Locality 1000A. According to Sinclair [MS] and a photograph in the Princeton University Archives, Locality 1000A is near the head of *Aphelops* Draw. Here, the Snake Creek Formation rests directly on the Sheep Creek [fig. 6E]. The Olcott Formation is not present.)

CLASS MAMMALIA

ORDER RODENTIA

FAMILY MYLAGAULIDAE

Mylagaulus monodon Cope, 1881: Matthew and Cook, 1909b, pp. 379-380. (AMNH 13866-13868, referred specimens, 1908 expedition, from *Aphelops* Draw.)

FAMILY SCIURIDAE

Otospermophilus matthewi Black, 1963, pp. 200-204, pl. 18, fig. 2. (Type AMNH 17578, 1918 expedition, from *Aphelops* Draw.)

FAMILY CASTORIDAE

Eucastor cf. *tortus* Leigy, 1858: Stirton, 1935, pp. 429-431. (AMNH 18849 from *Aphelops* Draw.)

Castor cf. *californicus* (Matthew, 1932, pp. 4, 5, fig. 5), Stirton, 1935, pp. 446, 447. (P₄, AMNH 20489; P⁴, AMNH 21464, collected from the Pits by Thomson in 1923.)

Dipoides sp., Stirton, 1935, p. 444, figs. 129-131. (Stirton, 1935, p. 444, cited AMNH 21465, M³ and lower molar, from the Pits, and UCMP 30573 as collected from "the first draw east of East *Pliohippus* Draw." This would have been on the head of Pigeon Draw where the outcrops are small.)

ORDER EDENTATA

FAMILY MEGALONYCHIDAE

Megalonyx curvidens Matthew, 1924a, pp. 149-150, fig. 40: Hirschfeld and Webb, 1968, pp. 235-238, fig. 6. (Thomson collected the type, AMNH 17601, a right M₃, in 1918, from *Aphelops* Draw; AMNH 20493, a molar, in 1923, and AMNH 21460, in 1925, from the Pits.)

ORDER CARNIVORA

FAMILY CANIDAE

Aelurodon validus (Matthew and Cook, 1909b, pp. 371-372, fig. 2) Stirton and VanderHoof, 1933, p. 179 (as *Osteoborus validus*). (Type AMNH 14147, 1908 expedition. On the strength of referred specimens, AMNH 17580 and 17581 from Quarry 1 in *Aphelops* Draw, from the 1918 expedition, the type of *A. validus* is tentatively assigned to *Aphelops* Draw.)

Matthew (1924a, p. 100) referred an upper jaw (AMNH 17580) collected in *Aphelops* Draw to *Aelurodon haydenianus validus*, and remarked that it was "probably the same as the lower jaw . . . described in 1909" (AMNH 14147; see Matthew and Cook, 1909b, p. 371, fig. 2) as "*A. haydeni validus* mut. nov." An upper jaw (AMNH 17581) was also collected from *Aphelops* Draw, and is here referred to *Aelurodon validus*.

The exact site is not known for the following specimens. The Johnson Member outcrops in *Aphelops* Draw are larger and more productive

than those in *Pliohippus* Draw, and for this reason we are tentatively assigning these canids to the *Aphelops* Draw Fauna:

Tomarctus propter Cook and Macdonald, 1962, p. 562, fig. 2. (Type HC 658 = AMNH 81007, collected by Cook in 1924.)

Leptocyon vafer (Leidy, 1858) Matthew, 1918, pp. 189-190. (Whitford and Stoll collected AMNH 17201 and 17202 in 1916.)

FAMILY MUSTELIDAE

Leptarctus sp. A lower jaw with P₄ (AMNH 17579) collected in *Aphelops* Draw in 1918.

FAMILY FELIDAE

Machairodus (Heterofelis) coloradensis Cook, 1922, p. 7: Martin and Schultz, 1975, p. 56. (The type CMNH 211 is a partial skull from near Wray, Yuma County, Colorado.)

In 1922 a lower jaw (AMNH 18920) collected from *Aphelops* Draw, which Matthew (1924a, pp. 147, 148, fig. 39) referred to *Machairodus catacopis* Cope, 1887, and at which time, he synonymized Cook's *M. coloradensis* with *M. catacopis*. Additional material from the type locality of *M. catacopis* in Smith County, Kansas, and additional specimens of *M. coloradensis* from Sherman County, Nebraska, convinced Martin and Schultz (1975) that *M. coloradensis* is a valid species. Martin and Schultz (1975) assigned the type of *M. catacopis* Cope to *Nimravides* Kitts, 1958.

ORDER PROBOSCIDEA

FAMILY MAMMUTIDAE

Pliomastodon matthewi (Osborn, 1921, pp. 4, 6) Osborn, 1936, pp. 157-159, 427. (Type AMNH 18237, collected by Thomson in 1918 from Quarry 1, *Aphelops* Draw. AMNH 18238, 18239, were also collected in the type locality. AMNH 19248a, 19248b were collected in the Pits, fig. 2).

FAMILY GOMPHOTHERIIDAE

Serridentinus nebrascensis Osborn, 1924, p. 41: 1936, pp. 427, 473. (Thomson collected the type AMNH 18240 in 1918 from Quarry 1, *Aphelops* Draw, AMNH 19248, 21451, 21455, from the Pits. Osborn, 1936, p. 429,

stated: "*Serridentinus nebrascensis* . . . may prove to be the same as the subsequently *Serridentinus anguirivalis* Osborn, 1926, in which case *S. anguirivalis* is synonym.")

Serridentinus anguirivalis (Osborn, 1921, pp. 4, 6); Osborn, 1936, pp. 425-428. (Type AMNH 17217, collected by Whitford and Stoll in 1916 from an unknown site. Osborn, 1936, removed a referred specimen from *Mastodon matthewi* and made it the type of *S. anguirivalis*. AMNH 19248e, 19248g, 19248h, 19248i, all questionably referred to *S. anguirivalis*, and 19248k, were collected by Thomson in 1923 from the Pits.)

Rhynchotherium anguirivale (Osborn, 1926, p. 13, fig. 11); 1936, pp. 491-493. (Referred specimens AMNH 19248c, 19248f from the Pits.)

ORDER PERISSODACTYLA

FAMILY RHINOCERATIDAE

Aphelops malacorhinus mutilus Matthew, 1924a, pp. 150-151, figs. 41-43. (Type AMNH 17584, skull, collected in 1918 by Mrs. Albert Thomson in *Aphelops* Draw.)

FAMILY EQUIDAE

"*Hipparion*" cf. *eurystyle*, referred: AMNH 21542, four detached lower teeth, collected in 1925 from the Pits.

"*Hipparion*" cf. *lenticulare*, referred: AMNH 21542, one upper and five lower detached teeth from *Aphelops* Draw.

Dinohippus leidymanus, referred: AMNH 17597, a maxilla with P³-M³, collected in 1918 from *Aphelops* Draw. Numerous detached upper and lower teeth were collected from both the Pits and *Aphelops* Draw by Thomson in 1918 and 1925.

ORDER ARTIODACTYLA

FAMILY MERYCOIDODONTIDAE

Ustatochoerus major (Leidy, 1858, p. 26.) Schultz and Falkenbach, 1941, p. 21. (Type USNM 439 right maxilla with P³-M², collected by F. V. Hayden in 1857 from an unknown site along the Niobrara River, Nebraska.)

In 1918 Thomson collected a partial skull (AMNH 17589) from *Aphelops* Draw. In 1908 Cook collected a partial right ramus (AMNH

14059) with P₁-P₄, but no exact site was given, only that the specimen was from the general area.

SUBORDER TYLOPODA

FAMILY CAMELIDAE

Megatylopus sp. A lower jaw (AMNH 17590), a maxilla (AMNH 17594), a metacarpus (AMNH 17591), and a metatarsus (AMNH 17592) collected by Thomson in 1918 from *Aphelops* Draw.

Procamelus robustus. Matthew (1932, pp. 6, 7, fig. 7) referred a lower jaw and skeletal parts (AMNH 20478) to *P. robustus*, remarking that "While the horizon of this specimen is uncertain, it is probably nearer to Lower than to Upper Snake Creek." The data with the specimen reads "Sperry Pasture, West Draw" where no rocks referable to the Olcott Formation are present, but where the lower part of the Johnson Member occurs.

FAMILY ANTILOCAPRIDAE

(?) *Texoceros altidens* (Matthew, 1924a, pp. 200-206, fig. 60). (Type AMNH 18981, 1918 expedition, from *Aphelops* Draw. Referred specimens are from *Pliohippus* Draw.)

Matthew (1924a, p. 201) pointed out that the holotypic M₃ differs from *Merycodus* in its larger size, the development of the fourth lobe, and its greater hypsodonty. Frick (1937, p. 507) questionably referred the species to *Texoceros*, but noted that the teeth are shorter crowned than in specimens referable to *Texoceros* from Oklahoma.

FAMILY BOVIDAE

Neotragocerus improvisus Matthew and Cook, 1909b, pp. 413, 414, fig. 26. (Type AMNH 14141, horn-core collected in 1908 in *Pliohippus* Draw. See ZX Bar Local Fauna, p. 360, for explanation.)

In 1947 Skinner collected a partial horn-core (F:AM 52140) from a Snake Creek channel cut deeply into the Sheep Creek Formation (fig. 6E) between *Merychippus* Draw and North Snake Den Hill. The deposits in this channel are referred to the lower part of the Johnson Member and the fossils to the *Aphelops* Draw Fauna.

THE ZX BAR LOCAL FAUNA (LATE HEMPHILLIAN), JOHNSON MEMBER

CLASS MAMMALIA

ORDER INSECTIVORA

FAMILY TALPIDAE

Gaillardia thomsoni Matthew (1932, pp. 5, 6, fig. 6): Hutchison (1968, pp. 46-54). (Type AMNH 20508, right ramus with P₃, P₄, M₃, collected by Thomson, 1922 expedition, from *Pliohippus* Draw.)

Matthew (1932, p. 6) named *Gaillardia thomsoni* on the basis of incisors reduced to a single large tooth. On the basis of a lineage that evolved independently from a uropsiline stock, Hutchison (1968, p. 46) proposed a new subfamily, Gaillardinae, for this aquatic talpid known from Hemphillian age deposits in Nebraska and Oregon.

FAMILY HETEROMYIDAE

Perognathus coquorum Wood, 1935, pp. 105-107. (Type HC 702 =AMNH 97845 from East *Pliohippus* Draw.)

ORDER EDENTATA

FAMILY MEGALONYCHIDAE

Megalonyx curvidens Matthew, 1924a, pp. 149-150, fig. 40: Hirschfeld and Webb, 1968, pp. 235-238, fig. 6. The type, AMNH 17601, is from *Aphelops* Draw.)

The following specimens are from East *Pliohippus* Draw: In 1931 Cook (MS) collected two proximal phalanges, AMNH 81034 and AMNH 85970 from "high exposures about 100 yards east of where 'complete' *Pliohippus* skeleton was found." Skinner collected F:AM 77800, a left ramus and symphysis with canines and cheek teeth (see Hirschfeld and Webb, 1968) from about 10 feet above the "*Pliohippus*" *leidyanus* site. F:AM 77801, a humerus, is from East *Pliohippus* Draw.

ORDER CARNIVORA

FAMILY CANIDAE

Osteoborus direptor (Matthew, 1924a) Stirton and Vanderhoof, 1933, p. 77. (Type AMNH

18919, 1922 expedition, from East *Pliohippus* Draw.)

Osteoborus secundus (Matthew and Cook, 1909b) Stirton and Vanderhoof, 1933, p. 178. (Type AMNH 13831, 1908. The exact site is not known for this specimen. On the basis of morphologic similarities to other taxa from Late Hemphillian, AMNH 13831 is tentatively assigned to the ZX Bar Local Fauna.)

FAMILY MUSTELIDAE

Pliotaxidea nevadensis (Butterworth, 1916) Cook and Macdonald, 1962, pp. 566-567. (Referred specimen AMNH 81019, collected by Cook in 1916 from "*Pliohippus*" *leidyanus* level, *Pliohippus* Draw.)

FAMILY URSIDAE

Agriotherium sp. A right M² (HC 360 =AMNH 81500) collected by Cook in 1916 (MS) in the "Snake Creek Beds, Typ. Loc."

A later entry on Cook's (MS) catalogue card, "Olcott Hill) Upper Beds" would put this taxon in the Late Clarendonian (Laucomer Member of the Snake Creek Formation). All other occurrences have been in Late Hemphillian age deposits. The molar agrees in fossilization with other fossils in *Pliohippus* Draw. It is tentatively held in the ZX Bar Local Fauna pending discovery of other Clarendonian occurrences.

ORDER PERISSODACTYLA

FAMILY EQUIDAE

Dinohippus leidyanus (Osborn, 1918, p. 162, fig. 130) Quinn, 1955, pp. 43-46. (Type AMNH 17224 [Osborn mistakenly gave 17724], skull, jaws, and postcranial elements collected in 1916 by Cook in East *Pliohippus* Draw.)

A photograph (AMNH 101787) taken by Thomson post-1916 shows Osborn and Barbour (Nebraska State Museum), and H. J. Cook of Agate, standing at the discovery site of *Dinohippus leidyanus*. The photograph and Cook's (MS) frequent references to this locality are the clues to the provenance of *D. leidyanus*, as well as that of another critical specimen,

for example, *Neotragocerus improvisus* (p. 360).

Pliohippus has been regarded by most authors as the direct ancestor of *Equus*. One rule of thumb for allocating Late Tertiary horses to *Pliohippus* was the requirement that upper cheek teeth have simple patterns, a character that the type of *Dinohippus leidyani* (AMNH 17224) shares with *Pliohippus* species. Stratigraphically controlled collections have since made it possible to show that a chronocline of *Pliohippus* species with dual facial fossae and simple, highly curved teeth became a dead-end phylum during Early Hemphillian time, or were so scarce in living numbers that no examples have been found. Osborn (1918, pp. 146, 162) explained that the absence of the large malar and lacrimal fossae in the type of *Pliohippus leidyani*, which were present in other *Pliohippus* species, was because these fossae were "secondary characters, strong and double in males, single and feebly developed in females." Among other characters, Quinn (1955, p. 43) recognized the absence of facial fossae in *Pliohippus leidyani*, however, as the basis for establishing his genus, *Dinohippus*, and remarked that *D. leidyani* "appears to have had a common ancestry with *Equus*."

A few characters easily separate *Dinohippus* from *Pliohippus*. Other more detailed characters are not included in the present paper because they require illustrations. (1) *Dinohippus* has a shallow nasal maxillary fossa well forward (anterior) of the orbit and an expanded facial crest with no malar fossa, except for an occasional scar for the attachment of the levator labialis. The protocones on P^2-M^3 are usually free from the hypocones; the hypoconal groove is usually retained to the base of the tooth, and the hypocone thus remains a distinct entity. *Pliohippus* has a broadly expanded lacrimal fossa (closer to the orbit than in *Dinohippus*) that becomes deeper and more pocketed in later examples. The facial crest of *Pliohippus* invariably has a malar fossa that becomes more deeply pocketed in later forms. In *Pliohippus* the protocones on M^1-M^3 are usually united with the hypocones in late wear states; the hypoconal groove is shallow, forming hypoconal fossettes on P^2-M^3 , and is lost early in wear.

Dinohippus is the dominant equid in Hemphillian collections, and is the only equid so far

identified in the ZX Bar Local Fauna. *Dinohippus* is scarce in Clarendonian and Valentinian collections whereas *Pliohippus* is one of the dominant forms. *Dinohippus* has not been found in Barstovian age deposits.

ORDER ARTIODACTYLA

FAMILY TAYASSUIDAE

Prosthennops (Prosthennops) serus (Cope, 1878, pp. 224-225), Matthew, 1924a, p. 179. (Type AMNH 8511, a mandible lacking angles and right M_3 , collected by Russell S. Hill from the "Loup Fork beds" of Sappa Creek, a drainage of the Republican River in northwestern Kansas.)

Matthew (1924a, p. 179) "provisionally" referred to *Prosthennops serus* a fragmentary skull (AMNH 17582) from East *Pliohippus* Draw that compared in size and dentition to a lower jaw from the same beds that he had also assigned to Cope's *P. serus*. The partial skull (AMNH 17582) from East *Pliohippus* Draw differed so greatly from another skull of *Prosthennops* (viz., Gidley's type of *P. crassigenis*) that Matthew (1924a) proposed the subgenus *P. (Macrogenis) crassigenis* for tayassuids whose zygomatic arches were expanded into massive lateral knobs.

When Gidley (1904, p. 265) erected the genus *Prosthennops* he mentioned Cope's species, *Dicotyles serus*, but did not state specifically that it was the type of *Prosthennops*. Gidley derived his generic characters from the skull that he described as *Prosthennops crassigenis*, and thus left the genus with two species, neither of which was clearly designated as the type. As first revisor Matthew (1924a, p. 179) unequivocally designated *Prosthennops serus* as the type of *Prosthennops* when he selected *P. crassigenis* as the type of his new subgenus *P. (Macrogenis)*. Hay's (1930) designation of *P. crassigenis* as the type of *Prosthennops* and his synonymy of *Macrogenis* with *P. crassigenis* is not here considered applicable. *Prosthennops (Prosthennops) serus* is therefore the type species (type by subsequent designation) in accordance with Article 69a in the International Code (Stoll and others, 1961).

?FAMILY MERYCOIDODONTIDAE

Ustatochoerus cf. major Schultz and Falkenbach,

1941, pp. 16, 17, 21. (The type, USNM 439, a partial right maxilla, was found by F. V. Hayden in 1857 in an unknown spot along the Niobrara River.)

In 1947 Skinner collected a maxilla with M^2 - M^3 (F:AM 95589) from the upper part of the Johnson Member in *Plihippus* Draw, slightly above Cook's *Plihippus leidyanus* site of 1916. The presence of the maxilla in the upper part of the Johnson Member is a fact, but the occurrence of *U. major* in Early or Late Hemphillian times is open to question (i.e., the specimen may have been reworked from older deposits). If other specimens of *U. major* are found in early or late Hemphillian deposits, however, this occurrence might then be considered incontrovertible.

SUBORDER TYLOPODA

FAMILY CAMELIDAE

Megatylopus gigas Matthew and Cook, 1909b, pp. 396-401, figs. 16-18; Webb, 1965, p. 40. (Type AMNH 14071, a skull collected by Thomson in 1908.)

Matthew and Cook (1909b, p. 396) cited Thomson as the collector; the American Museum field lists for 1908 also cited Thomson as the collector, and the locality as "Quarry 3" (not to be confused with Thomson's Quarry 3 of 1918; present paper, table 4). We suspect but cannot confirm that the 1908 Quarry 3 was in *Plihippus* Draw. Webb (1965, p. 42) stated: "The type specimen was collected by Harold Cook in *Plihippus* Draw a few feet from the type skeleton of *Plihippus leidyanus* and in the same channel . . . (Cook, pers. comm. at the site, 1962)." This statement seems to credit Cook as the collector of *Megatylopus gigas*, but we believe that Cook's statement to Webb was meant to be collective (i.e., "This is the place we found . . ."). Significantly, Cook's statement verified the site of the 1908 AMNH Quarry 3 as *Plihippus* Draw where other specimens referable to *Megatylopus* have been found. A palate, F:AM 41544, was collected in 1947 by Skinner from the east fork of *Plihippus* Draw, a few feet from, but stratigraphically higher than, the site of the type of *Dinohippus leidyanus*.

Other specimens referable to *Megatylopus*

have been found in *Aphelops* Draw (p. 357), as well as in Olcott and Kilpatrick quarries in the Laucomer Member on Olcott Hill (figs. 2, 4A).

SUBORDER RUMINANTIA

FAMILY CERVIDAE

Pediomeryx cf. *hemphillensis* Stirton, 1936, pp. 644-647, fig. 1. (Type UCMP 30703, right ramus with P_2 - M_3 from Coffee Ranch Quarry, Hemphill County, Texas, type locality of the Hemphillian Fauna.)

Cook collected two upper molars (HC 665 =AMNH 83458 and HC 680 =AMNH 83457) from *Plihippus* Draw. Cook (1922b, pp. 14, 15, fig. no number) provisionally referred a ramus with P_2 - M_3 (HC 365 =AMNH 83500) to *?Drepanomeryx falciformis* Sinclair, 1915, from the Olcott Formation in West Sinclair Draw. Cook (1922b, p. 14) stated that the ramus (AMNH 83500) came "from the typical *Plihippus* horizon of the Snake Creek Beds . . . a few yards south of the spot . . . where *Plihippus* was discovered." The ramus (AMNH 83500) is referred to *Pediomeryx* cf. *hemphillensis* as is the molar (AMNH 83458) that came from the same site and zone. This specimen (AMNH 83458) is important in establishing *Plihippus* Draw as the provenance of *Neotragocerus improvisus* type specimen (present paper, p. 361). The other molar (AMNH 83457) that Cook catalogued as "*?Neotragocerus*," also came from *Plihippus* Draw and is here referred to *Pediomeryx*.

FAMILY BOVIDAE

Neotragocerus improvisus Matthew and Cook, 1909b, pp. 413, 414, fig. 26. (Type AMNH 14141, horn-core collected in 1908 in *Plihippus* Draw.)

Matthew (1910, fig. 162) published a photograph of East Sinclair Draw and labeled sediments "Snake Creek Beds *Neotragocerus* Zone" that are referable only to the Olcott Formation. (At that time Matthew and Cook, 1909, p. 363, considered all the loose unconsolidated channel fills as "Snake Creek.") No specific site was given by Matthew and Cook for the type of *Neotragocerus improvisus*, nor do the field notes in the American Museum Archives give a clue to its

provenance. The rare occurrences of this taxon (until 1947 represented only by the type), and its unexpected occurrence in Tertiary deposits made *N. improvisus* something of a mystery. Frick (1937, p. 543) questioned the occurrence of a bovid in the Tertiary and Simpson (1945, p. 543) classified *N. improvisus* with the Pleistocene Caprinae.

The occurrence of Hemphillian fossils in the Snake Creek Formation was not then clearly understood, and it remained for Cook (MS) in his reference to a cervid molar (AMNH 83458, present paper, p. 360) to remove any doubt about the type locality of *Neotragocerus improvisus*. Cook (MS) stated: "HC 665 [=AMNH 83458] ?Bovid (??Neotragoceras) Upper Molar [collected in 1933, came from the] Upper Snake Creek Beds, same site & coarse sand-gravel channel as the type of *Neotragoceras improvisus* . . . This channel bed cut through the bed deeply, in

which *Pliohippus leidyanus* skeleton occurred—just south of the latter locality, and so *has to be* a *later phase* of the Snake Creek deposits." Cook's (MS) data fixed the site of *N. improvisus* as *Pliohippus* Draw, where only the upper part of the Johnson Member is present.

Matthew and Cook (1909b, pp. 413, 414, fig. 27) cited two brachydont upper dentitions (AMNH 14136, 14137) as paratypes of *Neotragocerus improvisus*, although no association of dentition and horn-cores was known, nor has any been found. These are here referred to *Pedionomeryx* cf. *hemphillensis* (p. 360). The goatlike character of the horn-core of *N. improvisus* would lead one to expect teeth as hypsodont as those of its Old World relatives. Dentitions of *N. improvisus* may be unrecognized in Hemphillian collections and confused with those of anti-locaprids (e.g., *Texoceros*).

SUMMARY

The three formations that crop out in the Sheep Creek-Snake Creek area range in age from Early to Late Miocene. Most paleontologists have followed Matthew's division of the local faunas into the Sheep Creek, lower Snake Creek, and Upper Snake Creek faunas. Matthew (1924a, p. 73) tentatively suggested a fourth local fauna, the *Pliohippus leidyanus* "faunal zone," which, in the present paper, is the Late Miocene (Late Hemphillian) ZX Bar Local Fauna.

Although the "faunal zones," as presented by Matthew (1924a, pp. 64-68) have been accepted generally (in the sense of local faunas), the rocks from which they were derived have been assigned to various units in the local geologic sequence. At no time did Matthew define or describe the rocks from which his Lower Snake Creek Fauna was derived, although distinctions were made in the field between the channel deposits that yielded the Lower and Upper Snake Creek faunas. Matthew (1924a, p. 61) concluded that the "relation between the Snake Creek and Sheep Creek had not been clearly understood . . . the two representing different facies of the same formation or sequence of strata." In 1939 A. L. Lugen took a different view and expanded the Sheep Creek

Formation to include rocks (Olcott Formation) that yielded the Lower Snake Creek Fauna, and then extended the distribution of the Sheep Creek Formation far beyond its type area. Elias (1942) followed this concept and divided the type Sheep Creek into the Spotted Tail and correlated Sand Canyon members (typified in Dawes County, Nebraska, 50 miles to the north-east), and included the geographically separated and lithologically dissimilar Box Butte deposits in it. Galusha (1975) defined and mapped the Box Butte Formation as a stratigraphic unit separate in time and space from the Sheep Creek Formation.

We treat the Late Hemingfordian Sheep Creek rocks as a formation that is limited to outcrops in the study area with no lithologically distinct members, although two minor erosion cycles occurred within it during the aggradation phase. We recognize the Early Barstovian Olcott Formation (=Lower Snake Creek Beds) as separate from both the Sheep Creek and Snake Creek formations. The Olcott Formation is also broken by minor erosion cycles. The Snake Creek Formation is comprised of three new members: the Murphy Member, which carries an unnamed Early

Clarendonian local fauna, the Late Clarendonian Laucomer Member that has yielded the type Snake Creek Fauna, the Johnson Member that yielded the Early Hemphillian *Aphelops* Draw Fauna, and the Late Hemphillian ZX Bar Local Fauna.

The following summary of the geologic events is deduced from the present study:

1. In the 10-square-mile Sheep Creek-Snake Creek area the Harrison Formation (not the Marsland) forms the basement rocks for the overlying Sheep Creek, Olcott, and Snake Creek formations. *Daemonelix* and the Agate Lime are secondary features of the Harrison Formation that are not present in the study area but are characteristic features for north of Agate. Outcrops of the Marsland Formation directly overlie the Harrison Formation on Tower Hill $3\frac{1}{8}$ miles to the northwest of the study area and do not underlie the Sheep Creek Formation (fig. 6E).

2. Box Butte sediments are not present in the study area and are not the upper part of the Sheep Creek Formation as postulated by Cady (1940, p. 666) and Elias (1942), but are as Galusha (1975) showed, part of the deposits of another drainage system that is older than the Sheep Creek paleovalley, and its deposits and their faunas. The Sand Canyon Member of Elias (1942) in its type area is a distinctly younger (Early Barstovian) unit whose dark gray ash does not equate with the Sheep Creek Ash.

3. The characteristic equid in the Sheep Creek Formation is *Merychippus primus*, the detached teeth of which were collected from the basal conglomerate of the Sheep Creek Formation that underlies massive pinkish sandy silts. Schultz and Falkenbach (1947, p. 203), R. V. Lugn (MS), and Folsom (MS) suggested that these sandy silts were Marsland sediments.

4. Drainage systems other than those of the Box Butte and the Sheep Creek were present in northwestern Nebraska during Hemingfordian time, but their deposits were not continuous with that of the Sheep Creek Formation. Degradation during Sheep Creek time produced a broad, mature paleovalley in which deposition was interrupted at least twice (two distinct minor erosion surfaces are present in the type area). Four volcanic ashbeds, all bluish gray vitric tuffs,

are present in the type area of the Sheep Creek Formation (figs. 4C, 6E). Evernden et al. (1964) dated the Sheep Creek Ash (KA 891, glass) just above the highest occurrence of the Sheep Creek Fauna, at 14.7 m.y. Nearly 10 years later Naeser and Izett (present paper, p. 299) used the fission-track method on zircon in the same ash, which gave a date of 16.1 ± 3.7 m.y. and 15.3 ± 2.0 m.y. for the glass. Naeser's and Izett's dates are more compatible with the inferred geochronological position of the Sheep Creek Fauna than that of Evernden, et al.

5. After extensive erosion of Sheep Creek sediments, the Olcott drainage systems were superposed on the underlying Sheep Creek rocks. Profiles of several narrow, deep Olcott channels with nearly vertical walls have been exhumed by the present surface drainage, similar to channels forming today in the valleys of the comparatively young Niobrara and Snake rivers in north-central Nebraska.

Minor diastrophic movements, or other events during Olcott deposition, resulted in at least three subcycles in the Sinclair Draw area. The Lower Snake Creek Fauna is derived primarily from sediments making up the earlier part of the Olcott Formation deposition.

6. The erosional hiatus at the base of the Murphy Member (the oldest member of the Snake Creek Formation) represents time during Late Barstovian and Valentinian. No deposits or faunas referable to these land mammal ages have been found in the study area. Moreover, local deposition of the Snake Creek Formation during Clarendonian and Hemphillian times is preserved only as remnants of presumably more widespread deposits. The Murphy Member is restricted to an outcrop on Olcott Hill, East Draw, and the slump blocks in the Johnson Member channel deposit in East *Pliohippus* Draw. Matthew (1924a, p. 63) and Lugn (1939, p. 1255) thought that these sediments were part of the Sheep Creek Formation, but fossils taken *in situ* by Cook and Skinner are referable only to Early Clarendonian time.

7. The Laucomer Member, which lies in erosional contact on the Murphy Member on Olcott Hill, is the type member of the Snake Creek Formation. The Laucomer Member was de-

posited after rapidly flowing Snake Creek streams had cut narrow channel-trenches that were filled with bedload gravel and waterworn fossils. The Snake Creek Fauna is derived from these deposits.

8. The Early Hemphillian *Aphelops* Draw Fauna is derived from the lower part of the Johnson Member of the Snake Creek Formation in the northwest part of the study area.

9. The Late Hemphillian ZX Bar Local Fauna is derived from the upper part of the Johnson Member in the northwest part of the study area. This is the type locality for *Dinohippus leidyanus* (Osborn, 1918) Quinn, 1955.

10. The relatively high relief of the present topography in western Nebraska is the result of continued and extensive degradation since Late Hemphillian time.

LITERATURE CITED

- American Commission on Stratigraphic Nomenclature
1970. Code of stratigraphic nomenclature. Tulsa, Oklahoma, U.S.A., Amer. Assoc. Petrol. Geol., Inc., 22 pp.
- Black, C. C.
1963. [Dec. 30] A review of the North American Tertiary Sciuridae. Bull. Mus. Comp. Zool., Harvard Univ., vol. 130, no. 3, pp. 113-248, 8 figs., 22 pls.
- Brisson, M. J.
1762. Regnum animale in classes IX distributum sive synopsis methodica. Editio altera auctior. Leiden, Theodorum Haak, viii+296 pp.
- Brodkorb, P.
1964. Catalogue of fossil birds: Pt. 2 (Anseriformes through Galliformes). Bull. Florida State Mus., vol. 8, no. 3, pp. 195-335.
- Butterworth, E. M.
1916. A new mustelid from the Thousand Creek Pliocene of Nevada. Bull. Dept. Geol., Univ. California, vol. 10, pp. 21-24, 1 fig.
- Cady, R. C.
1940. The Box Butte Member of the Sheep Creek Formation, Nebraska. Amer. Jour. Sci., vol. 238, no. 9, pp. 663-667.
- Cady, R. C., and O. J. Scherer
1946. Geology and ground-water resources of Box Butte County, Nebraska. U.S. Geol. Surv. Water-Supply Paper 969, vi+102 pp., 4 figs., 9 pls.
- Cook, H. J.
1912. Faunal lists of the Tertiary formations of Sioux County, Nebraska. Nebraska Geol. Surv., vol. 7, pt. 5, pp. 33-45.
1914. A new canid from the lower Pliocene of Nebraska. *Ibid.*, vol. 7, no. 51, pp. 49-50, 3 pls.
1915. Notes on the geology of Sioux County, Nebraska, and vicinity. *Ibid.*, vol. 7, pt. 11, pp. 60-75, 1 map, 7 figs.
1917. First recorded amphibian from the Tertiary of Nebraska. (Abstract presented by W. D. Matthew.) Bull. Geol. Soc. America, vol. 28, p. 213.
- 1922a. Tooth of almost human type from the Lower Pliocene Snake Creek beds of western Nebraska. *Ibid.*, vol. 33, p. 214.
- 1922b. A Pliocene fauna from Yuma County, Colorado, with notes on the closely related Snake Creek beds, from Nebraska. Proc. Colorado Mus. Nat. Hist., vol. 4, no. 2, pp. 3-15, 14 pls.
- 1922c. In Osborn, H. F. *Hesperopithecus*, the first anthropoid primate found in America. Amer. Mus. Novitates, no. 37, pp. 1-5, 3 figs.
1930. New rhinoceroses from the Pliocene of Colorado and Nebraska. Proc. Colorado Mus. Nat. Hist., vol. 9, no. 4, pp. 44-51, 7 pls.
1951. Some considerations affecting the Miocene-Pliocene boundary question in vertebrate-bearing rocks in North America and Eurasia. Rept. Internatl. Geol. Congr., XVIII Session, Great Britain, 1948, pt. 11, pp. 85-92.
1965. Runningwater Formation, middle Miocene of Nebraska. Amer. Mus. Novitates, no. 2227, pp. 1-8, 3 figs.
- [MS.] Catalog of private collection of fossil specimens from Sioux County, Nebraska, collected from July 1906 to July 1962.

- Cook, H. J., and M. C. Cook
1933. Faunal lists of the Tertiary Vertebrata of Nebraska and adjacent areas. Nebraska Geol. Surv., no. 5, pp. 1-58, preface by G. E. Condra.
- Cook, H. J., and J. R. Macdonald
1962. New Carnivora from the Miocene and Pliocene of western Nebraska. Jour. Paleont., vol. 36, no. 3, pp. 560-567, 4 figs.
- Cope, E. D.
1874a. Report on the stratigraphy and Pliocene vertebrate paleontology of northern Colorado. Bull. U. S. Geol. and Geogr. Surv. Terr., ser. 1, no. 1, pp. 9-22.
1874b. On a new mastodon and rodent. Proc. Acad. Nat. Sci. Philadelphia, pp. 221-223.
1878. Descriptions of new Vertebrata from the upper Tertiary formations of the west. Proc. Amer. Phil. Soc., vol. 17, pp. 219-231.
1881. Review of the Rodentia of the Miocene period of North America. Bull. U.S. Geol. Surv. Terr., vol. 6, art. 15, pp. 361-386.
1887. A saber-toothed tiger from the Loup Fork beds. Amer. Nat., vol. 21, pp. 1019-1020.
1890. On two new species of Mustelidae from the Loup Fork Miocene of Nebraska. *Ibid.*, vol. 24, pp. 950-958.
1893. A preliminary report on the vertebrate paleontology of the Llano Estacado. Fourth Ann. Rept. Geol. Surv. Texas, 1892, pp. 1-89, 23 pls.
- Darton, N. H.
1903. Preliminary report on the geology and water resources of Nebraska west of the one hundred and third meridian. Prof. Paper U.S. Geol. Surv., no. 17, pp. 1-69, 23 figs., 43 pls.
- Elias, M. K.
1942. Tertiary prairie grasses and other herbs from the High Plains. Geol. Soc. Amer., Special Papers, no. 41, 176 pp., 17 pls.
- Evernden, J. F., D. E. Savage, G. H. Curtis, and G. T. James
1964. Potassium-argon dates and the Cenozoic mammalian chronology of North America. Amer. Jour. Sci., vol. 262, pp. 145-198, 1 fig.
- Folsom, J. R.
[MS.] The field stratigraphy and mapping of the Marsland Formation in Sioux County, Nebraska. Master's thesis, Univ. Nebraska, 1954.
- Frick, C.
1937. Horned ruminants of North America. Bull. Amer. Mus. Nat. Hist., vol. 69, xxviii+669 pp., 103 figs.
- Galbreath, E. C.
1953. A contribution to the Tertiary geology and paleontology of northeastern Colorado. *Vertebrata*, art. 4. Univ. Kansas Paleont. Contrib., vol. 13, 120 pp., 26 figs., 2 pls.
1956. Remarks on *Cynarctoides arcidens* from the Miocene of northeastern Colorado. Trans. Kansas Acad. Sci., vol. 59, no. 3, pp. 373-378.
- Galusha, T.
1975. Stratigraphy of the Box Butte Formation Nebraska. Bull. Amer. Mus. Nat. Hist., vol. 156, art. 1, 68 pp., 16 figs.
- Galusha, T., and J. C. Blick
1971. Stratigraphy of the Santa Fe Group, New Mexico. Bull. Amer. Mus. Nat. Hist., vol. 144, art. 1, 128 pp., 38 figs., 3 tables.
- Gidley, J. W.
1903. A new three-toed horse. Bull. Amer. Mus. Nat. Hist., vol. 19, art. 13, pp. 467-476.
1904. New or little known mammals from the Miocene of South Dakota. American Museum Expedition of 1903. Part I: Geological notes. Part III: Dicotylidae. *Ibid.*, vol. 20, pp. 241-246; 265-268, figs. 14, 15.
1907. Revision of the Miocene and Pliocene Equidae of North America. *Ibid.*, vol. 23, art. 35, pp. 865-934.
- Gregory, W. K.
1927. *Hesperopithecus* apparently not an ape nor a man. Science, no. 1720, vol. 66, pp. 579-581.
- Gregory, W. K., and M. Hellman
1923a. Notes on the type of *Hesperopithecus Harold cookii* Osborn. Amer. Mus. Novitates, no. 53, 16 pp., 6 figs.
1923b. Further notes on the molars of *Hesperopithecus* and of *Pithecanthropus*. Bull. Amer. Mus. Nat. Hist., vol. 48, art. 13, pp. 509-530, 15 figs.
- Hatcher, J. B.
1902. Origin of the Oligocene and Miocene deposits of the Great Plains. Proc. Amer. Phil. Soc., vol. 41, no. 169, pp. 113-131.

- Hay, O. P.
1930. Second bibliography and catalogue of the fossil Vertebrata of North America. Washington: Carnegie Institution, publ. 390, vol. 2, xiv+1074 pp.
- Hayden, F. V.
1863. On the geology and natural history of the Upper Missouri. Trans. Amer. Phil. Soc., n. s., vol. 12, art. 1, 218 pp.
- Hirschfeld, S. E., and S. D. Webb
1968. Plio-Pleistocene megalonychid sloths of North America. Bull. Florida State Mus., Biol. Sci., vol. 12, no. 5, pp. 213-296, 22 figs.
- Holland, W. J., and O. A. Peterson
1913. The osteology of the Chalicotheroidea. Mem. Carnegie Mus., vol. 3, no. 2, pp. 189-406, 115 figs., pls. 48-77.
- Hutchison, J. H.
1968. Fossil Talpidae (Insectivora, Mammalia) from the later Tertiary of Oregon. Bull. no. 11, Mus. Nat. Hist., Univ. Oregon, 117 pp., 98 figs.
- Izett, G. A.
1975. Late Cenozoic sedimentation and deformation in northern Colorado adjoining areas. Mem. 144. Geol. Soc. America, pp. 179-209, 13 figs.
- James, G. T.
1963. Paleontology and nonmarine stratigraphy of the Cuyama Valley Badlands, California. Pt. 1. Geology, faunal interpretations, and systematic descriptions of Chiroptera, Insectivora, and Rodentia. Univ. California Publ. Geol. Sci., vol. 45, iv+154 pp., 53 figs., 7 pls., 25 tables.
- Kitts, D. B.
1958. *Nimravides*, a new genus of Felidae from the Pliocene of California, Texas and Oklahoma. Jour. Mammal., vol. 39, pp. 368-375.
- Leidy, J.
1857. (read December, 1856). Notices of extinct Vertebrata discovered by Dr. F. V. Hayden, during the expedition to the Sioux country under the command of Lieut. G. K. Warren. Proc. Acad. Nat. Sci. Philadelphia, vol. 8, pp. 311-312.
1858. Notice of remains of extinct Vertebrata, from the valley of the Niobrara River, collected during the exploring expedition of 1857, in Nebraska, under the command of Lieut. G. K. Warren, U. S. Top. Eng., by Dr. F. V. Hayden. *Ibid.*, vol. 10, pp. 20-29.
1869. The extinct mammalian fauna of Dakota and Nebraska. Jour. Acad. Nat. Sci., Philadelphia, ser. 2, vol. 7, 472 pp., 30 figs.
- Loomis, F. B.
1924. Miocene oreodonts in the American Museum. Bull. Amer. Mus. Nat. Hist., vol. 51, art. 1, 37 pp., 26 figs.
- Love, J. D.
1970. Cenozoic geology of the Granite Mountains area, central Wyoming. U. S. Geol. Surv. Prof. Paper 495-C, viii+C154 pp., 61 figs., 10 pls., 13 tables.
- Lugn, A. L.
1938. The Nebraska State Geological Survey and the "Valentine Problem." Amer. Jour. Sci., ser. 5, vol. 36, no. 213, pp. 220-227.
1939. Classification of the Tertiary system in Nebraska. Bull. Geol. Soc. Amer., vol. 50, pt. 3, pp. 1245-1275, 1 pl., 2 tables.
- Lugn, R. V.
[MS.] The heavy mineral assemblages of the Sheep Creek beds in western Nebraska compared with similar assemblages in other formations in the same region. Master's thesis, Univ. Nebraska, 1955.
- Macdonald, J. R.
1954. A new *Pseudaelurus* from the Lower Snake Creek Fauna of Nebraska. Jour. Paleont., vol. 28, no. 1, pp. 67-69, 1 fig.
1956. A new Clarendonian mammalian fauna from the Truckee Formation of western Nevada. *Ibid.*, vol. 30, no. 1, pp. 186-202.
- McKenna, M. C.
1965. Stratigraphic nomenclature of the Miocene Hemingford group, Nebraska. Amer. Mus. Novitates, no. 2228, 21 pp., 1 fig.
- Martin, L. D., and C. B. Schultz
1975. Cenozoic Mammals from the Central Great Plains. Pt. 5. Scimitar-toothed Cats. *Machairodus* and *Nimravides*, from the Pliocene of Kansas and Nebraska. Bull. Univ. Nebraska State Mus., vol. 10, no. 1, pp. 55-63, 5 figs., frontispiece.
- Matthew, W. D.
1901. Fossil mammals of the Tertiary of northeastern Colorado. Mem. Amer.

- Mus. Nat. Hist., vol. 1, pp. 355-448, pls. 37-39, 34 figs.
1902. A horned rodent from the Colorado Miocene, with a revision of the *Mylagauli*, beavers, and hares of the American Tertiary. Bull. Amer. Mus. Nat. Hist., vol. 16, pp. 291-310, 17 figs.
- 1904a. A complete skeleton of *Merycodus*. *Ibid.*, vol. 20, pp. 101-129, 1 pl., 21 figs.
- 1904b. Part II.-Carnivora and Rodentia. In Matthew, W. D., and J. W. Gidley, New or little known mammals from the Miocene of South Dakota. American Museum Expedition of 1903. *Ibid.*, vol. 20, pp. 246-265.
1909. Faunal lists of the Tertiary Mammalia of the west. Bull. U. S. Geol. Surv., no. 361, pp. 91-138.
1910. Snake Creek Formation (Ogallala) of western Nebraska, *Neotragocerus* zone. In Osborn, H. F., The age of mammals in Europe, Asia and North America. New York, The Macmillan Co., pp. 353-356, fig. 162.
1915. The Tertiary sedimentary record and its problems. In Problems of American Geology, a series of lectures dealing with some of the problems of the Canadian Shield and of the Cordilleras, delivered at Yale University on the Silliman Foundation in December 1913. By William North Rice, etc. New Haven: Yale Univ. Press, pp. 377-478.
1918. Contributions to the Snake Creek Fauna; with notes upon the Pleistocene of western Nebraska, American Museum Expedition of 1916. Bull. Amer. Mus. Nat. Hist., vol. 38, art. 7, pp. 183-229, 20 figs.
- 1923a. Notes on the type of *Hesperopithecus haroldcookii* Osborn. In Gregory, W. K., and M. Hellman. Amer. Mus. Novitates, no. 53, pp. 11-13.
- 1923b. Stratigraphy of the Snake Creek fossil quarries and the correlation of faunas. (Abstract) Bull. Geol. Soc. Amer., vol. 34, p. 131.
- 1924a. Third contribution to the Snake Creek Fauna. Bull. Amer. Mus. Nat. Hist., vol. 50, art. 2, pp. 59-210, 63 figs.
- 1924b. Correlation of the Tertiary formations of the Great Plains. Bull. Geol. Soc. Amer., vol. 35, pp. 743-754.
1932. New fossil mammals from the Snake Creek quarries. Amer. Mus. Novitates, no. 540, 8 pp., 7 figs.
- Matthew, W. D., and H. J. Cook
- 1909a. (read January 29). Pliocene fauna from western Nebraska. Science, new ser., vol. 29, no. 735, pp. 196-197.
- 1909b. A Pliocene fauna from western Nebraska. Bull. Amer. Mus. Nat. Hist., vol. 26, art. 27, pp. 361-414, 27 figs.
- Matthew, W. D., and C. C. Mook
1933. New fossil mammals from the Deep River Beds of Montana. Amer. Mus. Novitates, no. 601, 7 pp., 2 figs.
- Mook, C. C.
1923. A new species of alligator from the Snake Creek beds. Amer. Mus. Nat. Hist. Novitates, no. 73, 13 pp., 5 figs.
- Nebraska State Department of Roads, Program and Planning Section
1960. General highway map, Sioux County, Nebraska, in cooperation with the U. S. Dept. Commerce, Bureau of Public Roads. Scale: 1 inch = 1 mile.
- Obradovich, J. D., G. A. Izett, and C. W. Naeser
1973. Radiometric ages of volcanic ash and pumice beds in the Gering sandstone (earliest Miocene) of the Arikaree Group, southwestern Nebraska. (Abstract) Geol. Soc. Amer., vol. 5, no. 6, pp. 459-528.
- Osborn, H. F.
1909. Cenozoic mammal horizons of western North America. Bull. U. S. Geol. Surv., no. 361, 90 pp.
1910. The age of mammals in Europe, Asia and North America. New York, The Macmillan Co., 8 vo., xvii+635 pp., 220 figs.
1918. Equidae of the Oligocene, Miocene, and Pliocene of North America; iconographic type revision. Mem. Amer. Mus. Nat. Hist., new ser., vol. 2, pt. 1, pp. 1-330, 173 figs., 44 pls.
1921. First appearance of the true mastodon in America. Amer. Mus. Nat. Hist. Novitates, no. 10, pp. 1-6, 2 figs.
1922. *Hesperopithecus*, the first anthropoid primate found in America. *Ibid.*, no. 37, pp. 1-5, 3 figs.
1924. Additional generic and specific stages in the evolution of the Proboscidea. *Ibid.*, no. 154, 5 pp.
1926. Additional new genera and species of

- the mastodontoid Proboscidea. *Ibid.*, no. 238, pp. 1-16.
1936. Proboscidea: A monograph of the discovery, evolution, migration and extinction of the mastodonts and elephants of the world. Vol. 1: Moeritherioidea, Deinotherioidea, Mastodontoida. xl+802 pp., 680 figs. Vol. 2: Stegodontoidea Elephantoida. xxvii+1675 pp., figs. 681-1244. New York, the American Museum of Natural History.
- Patton, T. H., and B. E. Taylor
1971. The Synthetoceratinae (Mammalia, Tylopoda, Protoceratidae). *Bull. Amer. Mus. Nat. Hist.*, vol. 145, art. 2, pp. 123-218, 37 figs.
- Peckham, A.
1961. Heavy minerals of the Miocene Harrison Formation in northwestern Nebraska. *Jour. Sed. Petrol.*, vol. 31, no. 1, pp. 52-62, 2 figs.
- Peterson, O. A.
1904. Osteology of *Oxydactylus*. *Ann. Carnegie Mus. Nat. Hist.*, vol. 2, no. 3, pp. 434-475, 3 figs., 12 pls.
1907. The Miocene beds of western Nebraska and eastern Wyoming and their vertebrate faunas. *Ann. Carnegie Mus. Nat. Hist.*, vol. 4, art. 3, pp. 21-72, pls. 9-19, 20 figs.
1909. A revision of the Entelodontidae. *Mem. Carnegie Mus.*, vol. 4, pp. 41-156, pls. 54-62, 80 figs.
- Quinn, J. H.
1955. Miocene Equidae of the Texas Gulf Coast Plain. *Publ. Bur. Econ. Geol.*, Univ. Texas, no. 5516, 82 pp., 5 figs, 14 pls.
- Rich, T. H. V., and P. V. Rich
1971. *Brachyerix*, a Miocene hedgehog from western North America, with a description of the tympanic regions of *Paraechinus* and *Podogymnura*. *Amer. Mus. Novitates*, no. 2477, 58 pp., 22 figs.
- Schultz, C. B.
1938. The Miocene of western Nebraska. *Amer. Jour. Sci.*, vol. 35, pp. 441-444.
1941. Marsland Formation. (Abstract) *Bull. Geol. Soc. Amer.*, vol. 52, no. 10, pt. 4, pp. 1990-1991.
- Schultz, C. B., and C. H. Falkenbach
1940. Merycochoerinae. A new subfamily of oreodonts. *Bull. Amer. Mus. Nat. Hist.*, vol. 77, art. 5, pp. 213-306, 18 figs.
1941. Ticholeptinae. A new subfamily of oreodonts. *Ibid.*, vol. 79, art. 1, 105 pp., 17 figs.
1947. Merychyinae, a subfamily of oreodonts. *Ibid.*, vol. 88, art. 4, pp. 157-286, 17 figs.
1949. Promerycochoerinae, a new subfamily of oreodonts. *Ibid.*, vol. 93, art. 3, pp. 69-198, 26 figs.
1968. The phylogeny of the oreodonts. *Ibid.*, vol. 139, 498 pp., 56 figs.
- Schultz, C. B., and T. M. Stout
1941. Guide for a field conference on the Tertiary and Pleistocene of Nebraska. Special Publ. Univ. Nebraska State Mus., 51 pp., 16 figs. 1 pl.
1961. Field conference on the Tertiary and Pleistocene of western Nebraska. Guidebook, Ninth Field Conf., Soc. Vert. Paleont., Special Publ. Univ. Nebraska State Mus., no. 2, pp. 1-55, 47 figs. July 1961.
- Simpson, G. G.
1945. The principles of classification and a classification of mammals. *Bull. Amer. Mus. Nat. Hist.*, vol. 85, xvi+350 pp.
- Sinclair, W. J.
1915. Additions to the fauna of the lower Pliocene Snake Creek beds (result of the Princeton University 1914 Expedition to Nebraska). *Proc. Amer. Phil. Soc.*, vol. 54, no. 217, pp. 73-95, 18 figs.
- [MS.] Field notes taken on the Princeton Nebraska Expedition. Notes on localities and collecting data taken in 1914.
- Skinner, M. F.
- [MS.] Field notes and lists for Frick Laboratory expeditions in the Sheep Creek-Snake Creek beds, Sioux County, Nebraska, from 1940-1975. *Frick Arch.*, Dept. Vert. Paleont., Amer. Mus. Nat. Hist.
- Skinner, M. F., and B. E. Taylor
1967. A revision of the geology and paleontology of the Bijou Hills, South Dakota. *Amer. Mus. Novitates*, no. 2300, pp. 1-53, 12 figs.
- Skinner, M. F., S. M. Skinner, and R. J. Gooris
1968. Cenozoic rocks and faunas of Turtle Butte, south-central South Dakota. *Bull. Amer. Mus. Nat. Hist.*, vol. 138, art. 7, pp. 381-436, 16 figs.

- Skinner, M. F., and B. J. MacFadden
[In press.] *Cormohipparion*, N. Gen. (Mammalia, Equidae) From the North American Miocene (Barstovian-Clarendonian), Jour. Paleont.
- Stirton, R. A.
1935. A review of the Tertiary beavers. Univ. California Publ., Bull. Dept. Geol. Sci., vol. 23, no. 13, pp. 391-458, 142 figs., 1 map, 2 charts.
1936. A new ruminant from the Hemphill middle Pliocene of Texas. Jour. Paleont., vol. 10, no. 7, pp. 644-647, 1 fig.
- Stirton, R. A., and V. L. Vanderhoof
1933. *Osteoborus*, a new genus of dogs, and its relation to *Borophagus* Cope. Univ. California Publ., Bull. Dept. Geol. Sci., vol. 23, no. 4, pp. 175-182, 3 figs.
- Stoll, N. R., and others (eds.)
1961. International Code of Zoological Nomenclature adopted by the XV International Congress of Zoology. London, International Trust for Zoological Nomenclature, London, xvii+176 pp.
- Tedford, R. H., T. Galusha, M. F. Skinner, B. E. Taylor, R. Fields, J. R. Macdonald, T. H. Patton, J. M. Rensberger, and D. P. Whistler
[MS.] Faunal succession and biochronology of the Arikarean through Hemphillian interval (Late Oligocene through Early Pliocene epochs), North America.
- Thomson, A.,
[MS.a] Ann. Rept. Dept. Vert. Paleont., Amer. Mus. Nat. Hist. for 1908.
[MS.b] *Ibid.*, for 1916.
[MS.c] *Ibid.*, for 1918.
[MS.d] *Ibid.*, for 1921.
[MS.e] *Ibid.*, for 1922.
[MS.f] *Ibid.*, for 1923.
[MS.g] *Ibid.*, for 1925.
[MS.h] *Ibid.*, for 1926.
[MS.j] *Ibid.*, for 1927.
- United States Department of Agriculture. Agricultural Adjustment Administration
1939-1940. Sioux County, Nebraska. Uncontrolled mosaic (4 inches = 1 mile). Washington, D. C.
- United States Department of Agricultural Stabilization and Conservation Service
1954. Sioux County, Nebraska. Aerial photograph CBE-7N, 128, 130, 132, 134, 168, 169, 171, scale, 8 inches = 1 mile. Aerial Photography Division, 2505 Parley's Way, Salt Lake City, Utah.
- United States Coast and Geodetic Survey
1941. Vertical Control Data. Second order leveling. Harrison to Mitchell. United States Department of Commerce, Coast and Geodetic Survey, Washington, D. C.
1961. Vertical Control Data. Second order leveling. Harrison to Mitchell. *Ibid.*, Washington, D. C.
- United States Geological Survey
1899. (Surveyed in 1895) Nebraska Whistle Creek Quadrangle, contour interval 20 feet, Washington, D. C., scale: 1:125,000.
1955. Alliance, Nebraska NK 13-6. Transverse Mercator projection. Contour interval 100 feet with supplementary controls at 50 foot intervals. Denver 2, Colorado, or Washington 25, D. C., scale 1:250,000.
1956. Scottsbluff, Nebraska NK 13-9. Transverse Mercator projection. Contour interval 100 feet with supplementary contours at 50 foot intervals. Denver 2, Colorado, or Washington 25, D. C., scale 1:250,000.
- Vanderhoof, V. L., and J. T. Gregory
1940. A review of the genus *Aelurodon*. Univ. California Publ., Bull. Dept. Geol. Sci., vol. 25, no. 3, pp. 143-164, 8 figs.
- Webb, S. D.
1965. The osteology of *Camelops*. Bull. Los Angeles Co. Mus. Sci., no. 1, pp. 1-54, 21 figs.
1969. The Burge and Minnechaduzza Clarendonian mammalian faunas of north-central Nebraska. Univ. California Geol. Sci., vol. 78, pp. 1-191, 466 figs.
- Wetmore, A.,
1923. Avian fossils from the Miocene and Pliocene of Nebraska. Bull. Amer. Mus. Nat. Hist., vol. 48, no. 12, pp. 483-507, 20 figs.
1926. Descriptions of additional fossil birds from the Miocene of Nebraska. *Ibid.*, no. 211, pp. 1-5, 6 figs.
1928. Additional specimens of fossil birds from the upper Tertiary deposits of Nebraska. *Ibid.*, no. 302, pp. 1-5, 2 figs.
1934. A fossil quail from Nebraska. The Condor, vol. 36, no. 1, p. 30, fig. 5.
1943. Two more fossil hawks from the Miocene of Nebraska. *Ibid.*, vol. 45, no. 6, pp. 229-231, 2 figs.
- Whitford, A. C.
[MS.a] Field notes taken on the Princeton Nebraska expedition. Notes on locali-

- ties and collecting data taken in 1914. PU Arch., Princeton Univ., Princeton, New Jersey.
- [MS.b] Ann. Rept. Dept. Vert. Paleont., Amer. Mus. Nat. Hist. for 1916.
- Williams, E.
1950. *Testudo cubensis* and the evolution of western hemisphere tortoises. Bull. Amer. Mus. Nat. Hist., vol. 95, art. 1, pp. 1-36, 2 figs., 8 pls., 3 tables.
- Wilson, J.
[MS.] Field notes, report, and field lists for Frick Laboratory expeditions in Sioux County, Nebraska, from 1932-1940. Frick Arch., Dept. Vert. Paleont., Amer. Mus. Nat. Hist.
- Wood, A. E.
1935. Evolution and relationship of the heteromyid rodents with new forms from the Tertiary of western North America. Reprinted from Ann. Carnegie Mus., vol. 24, pp. 73-262, 157 figs.
- Wood, H. E., II et al.
1941. Nomenclature and correlation of the North American continental Tertiary. Bull. Geol. Soc. Amer., vol. 52, 48 pp.
- Woodburne, M. O.
1969. Systematics, biogeography, and evolution of *Cynorca* and *Dyseohyus* (Tayasuidae). Bull. Amer. Mus. Nat. Hist., vol. 141, art. 2, pp. 271-356, 14 figs., pls. 41-51.

INDEX OF QUARRIES AND SYNONYMS

Figures 2-4A, B, C, 5D, 6E, 7F, 14-17

- Above Greenside (Wilson, 1935).299, 329
Above Long Quarry (Wilson, 1934). . . .305, 328
AMNH 1908 Quarry (Thomson MS, 1908) . .333
Aphelops Quarry.339, 357
Ashbrook Quarry (Wilson, 1937)298, 327
Boulder Quarry (Skinner, 1942). . .301, 302, 337
Buck Quarry (Skinner, 1941)328
Camel Quarry (Skinner, 1941).304, 329
Camel Quarry No. 5 (Wilson, 1937)329
Campsite-Echo Quarry, Antelope Draw (Wilson, 1934)284, 335
Channel Bed Sheep Creek Quarry 21 (Thomson, 1921)329
Channel C Hor., West Sinclair Draw, West Wall (Wilson, 1932)331, 334
Channel D, East Wall (Wilson, 1933). . . .331
Channel D, West Sinclair Draw (Wilson, 1932)331
Channel Z (Wilson, 1933)338
Conference Quarry (1967 American Museum Expedition)328
Cook's *Pliohippus* Quarry279, 340
Douglas Quarry (Skinner, 1943)330
Echo Quarry (Skinner, 1941). . . .304, 305, 335
Echo Quarry, Echo Valley Channel Bed, Antelope Draw (Wilson, 1939)335
East Hilltop Quarry (Skinner, 1946) . . .299, 326
East Jenkins Quarry (Skinner, 1942). . . .332
East Pocket, East Sinclair Draw, Snake Creek Beds (Cook MS, for AMNH 81077)330
East Ravine Quarry (Wilson, 1939) . . .299, 327
East Sand Quarry (Skinner, 1941)304, 331
East Sand Quarry, No. 9 (Wilson, 1937). . . .331
East Side Echo Quarry, Antelope Draw (Wilson, 1934)335
East Surface Quarry (Skinner, 1941).283, 304, 333
East Surface Quarry No. 2 (Wilson, 1937)304, 333
East Wall Quarry (Wilson, 1937)330
Far Surface Quarry (Skinner, 1941) . . .304, 334
Far Surface Quarry, No. 3 (Wilson, 1938) . .334
Grass Roots Quarry (Ghomson, 1926). .282, 336
Grass Roots Quarry, '25, H.F.O. Qu. 6336
Greenside Quarry (Wilson, 1935)297, 325
Hesperopithecus Site279, 281, 301
Hilltop Quarry (Wilson, 1934)298, 326
Hipparion Channel, *Aphelops* Draw (Wilson, 1934)339
Humbug Quarry (Wilson, 1936)305, 335
Jenkins Quarry (Wilson, 1940).332
Kilpatrick Quarry337
Kilpatrick Quarry, H.F.O. Qu. 7 (Thomson, 1926)282, 337
Long Quarry (Wilson, 1934)284, 297, 299, 305, 325
Lower Snake Creek Beds, Sinclair Draw, East Pocket (Cook MS for AMNH 8348)330
Mesoceras Quarry (Cook, 1925).279, 333
Mill and Floor of Mill quarries (Skinner, 1942)304, 305, 336
New Sand Quarry (Wilson, 1938)335

New Surface Quarry (Wilson, 1938)	334	Sinclair Quarry (Skinner, 1941)	331
North Thomson Quarry (Skinner, 1940)	326	Sinclair Quarry, No. 1, Hor. B (Wilson, 1932)	329
North Wall Quarry (Skinner, 1941)	330	Sinclair Quarry, No. 2, Hor. C (Wilson, 1932)	333
North Wall Quarry No. 7 (Wilson, 1937)	330	Sinclair Quarry, No. 4, Hor. A (Wilson, 1932)	329
Olcott Quarry	311, 338	Sinclair Quarry, No. 5, Hor. B (Wilson, 1932)	329
Olcott Quarry <i>Hipparion affine</i> channel (Skinner, 1946)	338	Sinclair Draw Quarry, No. 7, Hor. A (Wilson, 1932)	330
Olcott Quarry <i>Hipparion</i> Channel Bed (Wilson, 1936)	338	Snake Creek Beds (Whitford, 1916)	334
<i>Pliohippus</i> Draw (Matthew, 1924a, fig. 1)	340	Snake Creek Beds, Channel bed 100 yards west of Sinclair Draw . . . found by A. Thomson, 1921 (Cook MS for AMNH 8362).	330
Pocket 34 (Wilson, 1934)	333	Snake Quarry (Skinner, 1941)	329
Princeton Locality 1000A (Sinclair, 1915)	279, 339	Snake Quarry No. 1 (Wilson, 1937)	329
Princeton Locality 1000B (Sinclair, 1915)	279	South Humbug Quarry (Skinner, 1941)	335
Princeton Locality 1000C (Sinclair, 1915)	330, 331, 334, 338	South of <i>Pliohippus</i> Draw (Cook MS for HC 896)	339
<i>Prosynthetoceras</i> Quarry (Skinner, 1941)	305, 336	<i>Synthetoceras</i> Quarry (Skinner, 1941)	336
Quarry A (Thomson, 1921)	333	Sub A (Wilson, 1932)	331
Quarry B (Thomson, 1921)	329, 334	Target Quarry (Skinner, 1947)	328
Quarry C, Ashbrook Pasture (Thomson, 1921)	338	The Pits (Skinner, 1947)	339
Quarry 1 (Thomson's map)	281, 324, 339	The Pits. H.F.O. Qu. 5 (Thomson, 1923)	324, 339
Quarry 2 (Osborn, 1936, fig. 392)	329, 333, 324, 334	Thistle Quarry (Wilson, 1935)	299, 326
Quarry 2 (Thomson, 1908 for AMNH 14070)	324, 333	Thomson Quarry (Wilson, 1933)	283, 325
Quarry 3 (Osborn, 1936, fig. 392)	324, 338	Thomson Quarry, Lowest Snake Creek beds just east of Sinclair Draw (Cook MS for HC 467)	330
Quarry 3, Hor. C. (Wilson, 1932)	324, 334	Thomson's <i>Hipparion</i> Quarry (Wilson, 1938)	337
Quarry 4 (Osborn, 1936, fig. 392)	324, 340	Trojan Quarry	283, 304, 329
Quarry 5 (Osborn, 1936, fig. 392)	324, 339	Trojan Quarry, No. 4 (Wilson, 1937)	324, 329
Quarry 6, Grass Roots Quarry (Osborn, 1936, fig. 392)	324, 336	Version Quarry (Wilson, 1936)	334
Quarry 7, Kilpatrick (Osborn, 1936, fig. 392)	324, 337	Vista Quarry (Skinner, 1945)	299, 327
1916-21 Workings (Matthew, 1924a, fig. 1)	333	West Jenkins Quarry (Skinner, 1942)	332
Quarry 21 (Matthew, 1924a, fig. 1)	329, 334	West Sand Quarry (Skinner, 1941)	283, 304, 331
*Quarry (Matthew, 1924a, fig. 1)	338	West Sand Quarry, No. 8 (Wilson, 1937)	324, 331
Ravine Quarry (Wilson, 1937)	299, 327	West Sinclair Draw, Hor. A, Q. No. 6 (Wilson, 1932)	324, 330
Rhino Quarry (Wilson, 1937)	327	West Surface Quarry	334
Sand Quarry (Wilson, 1940)	332	West Surface Quarry, Channel C, West Sinclair Draw (Wilson, 1935)	331, 334
Sheep Creek Channel Bed, Antelope Draw (Wilson, 1933)	325	Where type of <i>Hesperopithecus haroldcookii</i> was found (Cook, MS, many citations)	281, 337
Sheep Creek Quarry (Matthew, 1924a, fig. 1)	325	Where type of <i>Pliohippus leidymanus</i> was found (Cook, MS, many citations)	279, 324, 340
Sheep Creek quarries 1922-1923 (Thomson MS, 1922, 1923)	325		
Sinclair Draw, East Quarry, Snake Creek Beds, Lower Pliocene (Cook MS for AMNH 6610)	330		
Sinclair Draw Quarry (Thomson, 1921)	331		
Sinclair Draw Quarry (Osborn, 1936, fig. 392)	331		

INDEX FOR FIGURES

Figure 1A, B.	275	Figure 9.	317
Figure 2 and overlay	277	Figure 10.	318
Figure 3 and overlay	291	Figure 11.	319
Figure 4A	295	Figure 12.	320
Figure 4B, C.	295	Figure 13.	321
Figure 5.	301	Figure 14.	323
Figure 6.	303	Figure 15.	329
Figure 7.	311	Figure 16.	338
Figure 8.	316	Figure 17.	341

BULLETIN OF THE AMERICAN MUSEUM OF NATURAL HISTORY



Volume 158
1976-1977

PUBLISHED BY ORDER OF THE TRUSTEES
NEW YORK : 1977

Edited by
FLORENCE BRAUNER

CONTENTS OF VOLUME 158

- Article 1. Revision of the Neotropical Cholinae. The Subgenus *Cholus* (*Cholus*) (Coleoptera, Curculionidae). By Patricia Vaurie. Pages 1-80, figs. 1-116. December 14, 1976 Price. \$4.30

- Article 2. Review of Ichthyodectiform and Other Mesozoic Teleost Fishes and the Theory and Practice of Classifying Fossils. By Colin Patterson and Donn E. Rosen. Pages 81-172, figs. 1-54. February 23, 1977 Price. \$4.95

- Article 3. A Synopsis of Asian Species of *Mus* (Rodentia, Muridae). By Joe T. Marshall, Jr. Pages 173-220, figs. 1-54, tables 1-5. February 28, 1977 Price. \$2.90

- Article 4. Small Rodents (Mammalia) from Eocene Deposits of San Diego County, California. By Jason A. Lillegraven. Pages 221-262, figs. 1-32, tables 1-11. March 10, 1977 Price. \$2.30

- Article 5. Stratigraphy and Biostratigraphy of Late Cenozoic Deposits in Central Sioux County, Western Nebraska. By Morris F. Skinner, Shirley M. Skinner, and Raymond J. Gooris. Pages 263-371, figs. 1-17, tables 1-14. May 26, 1977 . . Price. \$7.60

